

AN
EINSTEIN ENCYCLOPEDIA

ALICE CALAPRICE • DANIEL KENNEFICK • ROBERT SCHULMANN



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ALICE CALAPRICE, DANIEL KENNEFICK, AND ROBERT SCHULMANN

PRINCETON UNIVERSITY PRESS
PRINCETON AND OXFORD

Copyright © 2015 by Princeton University Press
Published by Princeton University Press, 41 William Street,
Princeton, New Jersey 08540
In the United Kingdom: Princeton University Press, 6 Oxford Street,
Woodstock, Oxfordshire OX20 1TW

press.princeton.edu

Jacket photographs: Albert Einstein speaks at an event in favor of a Refugee Foundation, Royal Albert Hall, London, 1933 (b/w photo), English photographer, (20th century) / Bridgeman Images. Einstein at the Swiss Federal Patent Office, photo by Lucien Chavan. Photograph of Einstein playing the violin courtesy of the Leo Baeck Institute.

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Library of Congress Cataloging-in-Publication Data

Calaprice, Alice, author.

An Einstein encyclopedia / Alice Calaprice, Daniel Kennefick, and Robert Schulmann.

pages cm

Includes bibliographical references and index.

ISBN 978-0-691-14174-9 (hardcover : alk. paper) 1. Einstein, Albert, 1879–1955—Encyclopedias.

2. Physicists—Biography—Encyclopedias. 3. Relativity (Physics)—History—Encyclopedias. 4.

Physics—History—20th century—Encyclopedias. I. Kennefick, Daniel, author. II. Schulmann,

Robert J., author. III. Title.

QC16.E5C343 2015

530.092—dc23

2015008233

British Library Cataloging-in-Publication Data is available

This book has been composed in in Minion Pro

Printed on acid-free paper. ∞

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

In memory of Walter Hunziker (1935–2012), mathematical physicist, unflagging
supporter of Einstein research, and steadfast friend

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Preface

To mark the 100th anniversary of Albert Einstein's greatest accomplishment—the general theory of relativity—we introduce a reference work that presents the many sides of his life and work: the personal, scientific, spiritual, ethical, intellectual, and sociopolitical. The selections reflect our personal vision based on our collective knowledge and experience, but we have aimed to include subject matter that will interest not only scientists but also the general public.

Organization of the Book

Einstein made indelible contributions in very different areas of endeavor—in physics as a giant of the first rank, and in the human sphere as a moral and humanitarian icon. Thus, we have divided our volume into three parts, with each one tracing a different aspect of his life.

The book is not designed to be read cover to cover, but to be consulted and browsed according to the reader's interests. What follows is a guide that, we hope, offers readers ready accessibility to the many topics that help define Einstein.

We begin the volume with a chronology of Einstein's life and significant achievements, followed by his credo, "What I Believe," written in midlife in 1930, in which he summarized his way of looking at the world, his *Weltanschauung*. The three parts of the book follow: [Part I](#) addresses Einstein's personal and family life; [Part II](#) his scientific accomplishments and related material; and [Part III](#) his nonscientific involvements, including his Jewish identity. Within each of these three major parts, we have arranged many of the topics in alphabetical order, though a few historical events, such as birth and death information and sections of [Part III](#), are in chronological sequence. Subentries are listed alphabetically when possible and chronologically when necessary, the latter arrangement used generally with historical subjects. If we violated our general rule on the rare occasion when we could not come up with a clear solution for placement, we hope that readers will overlook the minor lapse. Supplementary information that did not fit neatly into the three major categories appears in appendixes. The contents and index, as well as the many cross-references, provide ways to navigate the book.

Sources

For much of the information in this volume, we relied on the Einstein Archives and the currently available volumes (1 to 14) of the comprehensive edition of *The Collected Papers of Albert Einstein*. We received valuable additional family information from the Einstein Archives' information officer, Barbara Wolff, at the Hebrew University in Jerusalem. Each of us also drew on our own experiences and memories from our work with these papers—an accumulated total of almost eighty years. We provide sources for direct quotations and often provide archival and other documentation for specific information so that readers can consult primary material. If we give only an author's last name and a short title of his or her work, readers can consult the References section at the back of the book for complete source information.

[Appendix A](#) discusses books about Einstein that we have often turned to—or rejected—in our own work. [Appendix B](#) addresses the complex copyright issues related to Einstein's works. [Appendix C](#) provides an annotated bibliography of Einstein's publications, listing what we believe are all the most important and representative publications from Einstein's various fields of interest.

Acknowledgments

We express our gratitude to Barbara Wolff of the Einstein Archives at the Hebrew University in Jerusalem for correcting some of our errors and supplying valuable

additional information and insights. Andor Carius, József Illy, Michel Janssen, Osik Moses, Jürgen Renn, Ze'ev Rosenkranz, Tilman Sauer, John Stachel, and Jeroen van Dongen helped to clarify a number of murky issues and points or offered suggestions on the many topics covered here, and we are grateful for their contributions. We are also very grateful to Thomas Ryckman for agreeing to provide a section on Einstein's philosophy of science. Anne Savarese, our editor at Princeton University Press, saw promise in our project, provided valuable suggestions, and made sure the manuscript became a book, and our copyeditor, Karen Verde, caught our infelicities and bloopers. Sara Lerner cheerfully and skillfully guided the book through production. We are grateful to the Press's readers for giving us input that we hope improves the book's organization, and for taking valuable time to challenge us on some topics. We also thank Diana Buchwald and the staff at the Einstein Papers Project, especially former editor Osik Moses, for helping with specific questions and leading us to selected photographs and documents; Barbara Wolff at the Einstein Archives for supplying facsimile certificates; and Princeton University Press and the Hebrew University of Jerusalem for granting permission to use copyrighted material.

Chronology

1879	March 14, Albert Einstein is born in Ulm, Germany, in the home of his parents, Hermann and Pauline Koch Einstein.
1880	Family moves to Munich.
1881	November 18, Einstein's sister, Maja, is born.
1884	Father shows him a compass, an instrument that makes a great impression on the five-year-old, showing that there are unseen forces in the world around him.
1885	In the fall, enters the Petersschule, a Catholic primary school, where he is the only Jew in class. Receives private Jewish religious instruction and becomes curious about religion; this curiosity ends by age twelve. Begins violin lessons.
1888	Enters Luitpold-Gymnasium (secondary school) in Munich.
1889–1905	Interest in physics, mathematics, and philosophy develops.
1894	Family moves to Milan, Italy, but Albert stays in Munich to finish school. Quits the Gymnasium at end of the year at age fifteen and joins his family in Milan.
1895	Attempts early admission to the Swiss Federal Polytechnical School in Zurich (the "Poly"; renamed the Federal Institute of Technology, known by its German acronym ETH, in 1911) in the fall at age sixteen, two years before the normal age, but fails the entrance exam despite good marks in science and math. Attends Aargau Cantonal School in the town of Aarau, Switzerland, while living in the home of one of the teachers.
1896	Renounces Württemberg (German) citizenship. In fall, graduates from the school in Aarau, allowing him to enter the Poly a year early. Moves to Zurich at end of October.
1899	Applies for Swiss citizenship at age twenty.
1900	Graduates from the Swiss Federal Polytechnical School with a teacher's diploma in mathematics and physics. Fails to obtain an assistantship at the Poly for the fall semester. In summer, tells his disapproving mother he plans to marry fellow student Mileva Marić. At end of the year, sends his first scientific paper to the premier German physics journal <i>Annalen der Physik</i> .
1901	Becomes a Swiss citizen. Seeks employment. Publishes his first scientific paper, "Conclusions Drawn from the Phenomena of Capillarity," in March in <i>Annalen der Physik</i> . In the summer, works as a substitute teacher at the technical secondary school in Winterthur, and in the fall as a tutor in a private boarding school in Schaffhausen. Maintains his relationship with Mileva. Begins work on his doctoral dissertation on molecular forces in gases, which he submits to the University of Zurich in November. December, applies for a position at the Swiss Federal Patent Office in Bern.
1902	Probably in late January, daughter "Lieserl" is born out of wedlock to Mileva in today's Serbia, where her family lives. Withdraws his doctoral dissertation from University of Zurich. June, begins a provisional appointment as Technical Expert, Third Class, at the Patent Office in Bern. October, his father dies in Milan.
1903	January 6, marries Mileva in Bern, where they take up residence. September, Einstein asks Mileva if "Lieserl" was registered, presumably in Serbia; no evidence of registration has ever been found. Around this time, Mileva becomes pregnant again.
1904	May 14, son Hans Albert is born in Bern. September, the provisional appointment at the Patent Office becomes permanent.

1905	Einstein's "Year of Miracles," during which he publishes five groundbreaking scientific papers.
1906	January 15, formally receives a doctorate from the University of Zurich. March 10, is promoted to Technical Expert, Second Class, at the Patent Office.
1907	While still at the Patent Office, seeks additional employment, including at the Zurich Cantonal School and at the University of Bern. Begins work together with his friends, the Habicht brothers, on a small induction machine (the so-called <i>Maschinchen</i>) for the measurement of small quantities of electricity.
1908	February, becomes <i>Privatdozent</i> (unsalaried lecturer) at the University of Bern. Sister Maja receives a doctorate in romance languages from the same university.
1909	May 7, is appointed Extraordinary (<i>Ausserordentlicher</i>) Professor of Theoretical Physics at the University of Zurich, effective October 15. Resigns from positions at the Patent Office and University of Bern. Receives his first honorary doctorate, at age thirty, from the University of Geneva. Attends meeting of the Gesellschaft Deutscher Naturforscher und Ärzte (Society of German Natural Scientists and Physicians) in Salzburg, where he suggests an early form of the wave-particle duality of light.
1910	March, sister Maja marries Paul Winteler, son of Einstein's <i>Hausvater</i> (landlord) in Aarau and brother of his first girlfriend, Marie. July 28, second son, Eduard ("Tete," "Teddy"), is born. October, completes a paper on critical opalescence and the blue color of the sky, his last major work in classical statistical physics.
1911	Accepts appointment as Professor of Theoretical Physics at the German University of Prague and director of its institute, effective April 1, and resigns his position at the University of Zurich. Moves his family to Prague. October 29, attends the first Solvay Conference in Brussels.
1912	Becomes reacquainted with divorced cousin Elsa Löwenthal née Einstein and begins a romantic correspondence with her as his own marriage deteriorates. Accepts appointment as Professor of Theoretical Physics at the ETH, his alma mater, in Zurich, beginning in October, and resigns his position in Prague.
1913	September, sons Hans Albert and Eduard are baptized in a Serbian Orthodox church in Novi Sad, Hungary (today in Serbia), their mother's hometown. November, is elected to the Prussian Academy of Sciences and is offered a position in Berlin, home of Elsa Löwenthal née Einstein. The offer includes a research professorship at the University of Berlin, without teaching obligations, and the directorship of a future Kaiser Wilhelm Institute of Physics. Resigns from the ETH.
1914	April, arrives in Berlin to assume his new position. Mileva and the children join him but return to Zurich end of July because of continuing marital problems. August, First World War begins. Co-signs "Manifesto to the Europeans" upholding European culture, probably his first public political statement.
1915	November, completes work on his general theory of relativity.
1916	Publishes "The Origins of the General Theory of Relativity" (later it would become his first book) in <i>Annalen der Physik</i> . Also publishes three papers on quantum theory. May, becomes president of the German Physical Society.
1917	February, writes his first paper on cosmology. October 1, begins directorship of the Kaiser Wilhelm Institute of Physics. Around Christmas, becomes bedridden for several months.
1918	November 9, German emperor abdicates. Einstein convinces revolutionary students to free the rector and professors of the

	University of Berlin who had been placed under arrest.
1919	February 14, is divorced from Mileva. Drawn to the Zionist cause through the efforts of Kurt Blumenfeld. May 29, during a solar eclipse, Sir Arthur Eddington experimentally measures the bending of light and confirms two predictions regarding general relativity; Einstein's fame as a public figure begins as the media spread the news later in the year. June 2, marries Elsa.
1920	February 20, his mother dies in Berlin. Anti-Semitism and incendiary attacks on relativity theory become more prevalent in Germany, even as Einstein maintains his loyalty. Becomes increasingly involved in nonscientific affairs.
1921	April and May, makes first trip to the United States, accompanying the Zionist leadership on a fund-raising tour to support the establishment of the Hebrew University in Jerusalem. Gives four lectures on relativity theory at Princeton University, later published as a book.
1922	Completes his first paper on a unified field theory. October, begins a six-month voyage to Japan, with numerous other stops in the Far East. Becomes ill with digestive issues. November, learns that he retroactively won the 1921 Nobel Prize in Physics.
1923	Visits Palestine and Spain on return trip.
1924	Stepdaughter Ilse marries Rudolf Kayser, a journalist and future Einstein biographer.
1925	Travels to South America. In solidarity with Gandhi, signs a manifesto against compulsory military service. Becomes an ardent pacifist. Receives the Copley Medal. Until 1928, serves on the board of governors of Hebrew University.
1926	Royal Astronomical Society of London awards him its gold medal.
1927	Hans Albert marries Frieda Knecht over both parents' objections.
1928	Becomes ill again, this time with a heart problem. Is confined to bed for several months and remains weak for a year. April, Helen Dukas is hired as his secretary; she remains with him as secretary and, later, housekeeper until his death.
1929	Begins lifelong friendship with Queen Elisabeth of the Belgians. June, receives Germany's Planck Medal.
1930	First grandchild, Bernhard, born to Hans Albert and Frieda. Stepdaughter Margot marries Dmitri Marianoff. Einstein spends several months at his summer cottage in Caputh, southwest of Berlin. Signs manifesto for world disarmament. December, visits New York and Cuba and stays (until March 1931) at the California Institute of Technology (Caltech) in Pasadena.
1931	Visits Oxford in May to deliver Rhodes Lectures and receives honorary doctorate. December, again en route to Pasadena.
1932	January–March, visits Caltech again. Returns to Berlin. Later, agrees to accept an appointment as professor at the Institute for Advanced Study, still in its planning stages, in Princeton, New Jersey. December, makes another visit to the United States.
1933	January 30, Nazis come to power in Germany. Resigns membership in the Prussian Academy of Sciences and never returns to Germany. Resides temporarily in Belgium, then visits Oxford to give the Spencer Lecture. Immigrates to the United States, arriving in New York on October 17.
1934	Is stripped of German citizenship (remains a Swiss citizen). July 10, Ilse dies in Paris at age thirty-seven of intestinal tuberculosis. Elsa becomes depressed. Margot moves to Princeton without her husband. Rudolf, Ilse's widowed husband, remains in Europe for the time being.
1935	Fall, moves to 112 Mercer Street, Princeton, where Einstein, Elsa, Margot, and Helen Dukas will live out their lives. Receives the Franklin Medal in Philadelphia.

1936	December 20, Elsa dies of exophthalmic goiter and pneumonia, complicated by heart problems.
1937	Margot and Dmitri divorce.
1939	Maja Winteler-Einstein moves in with her brother. August 2, signs the famous letter to President Roosevelt on the military implications of atomic energy. Second World War begins in Europe.
1940	Receives U.S. citizenship, along with Margot Einstein and Helen Dukas.
1941	December, United States enters Second World War after the Japanese bomb Pearl Harbor.
1943	Becomes consultant to the U.S. Navy Bureau of Ordnance, Section on Explosives and Ammunition.
1944	Newly handwritten copy of the original 1905 paper on the special theory of relativity raises \$6 million at auction; proceeds go to the war effort.
1945	Second World War ends. Retires officially from the Institute for Advanced Study; receives a pension at the same salary and keeps his office until his death.
1946	Maja suffers a stroke and becomes bedridden. Einstein chairs the Emergency Committee of Atomic Scientists. Urges the United Nations to form a world government for the control of armaments, maintaining it is the only way to achieve world peace.
1948	August 4, Mileva dies in Zurich. December, Einstein is diagnosed with a large aneurysm of the abdominal aorta.
1950	March 18, signs his last will, naming friend Otto Nathan as executor and Otto Nathan and Helen Dukas as co-trustees of his literary estate.
1951	June, sister Maja dies.
1952	Is offered the presidency of Israel, which he declines.
1954	Develops hemolytic anemia.
1955	April 11, writes his last signed letter, to Bertrand Russell, agreeing to sign a joint manifesto urging all nations to renounce nuclear weapons. April 13, the aneurysm ruptures. April 15, enters Princeton Hospital. April 18, Albert Einstein dies at 1:15 a.m.
1965	Eduard Einstein dies in Switzerland.
1973	Hans Albert Einstein dies in Woods Hole, Massachusetts.
1982	February 9, Helen Dukas dies in Princeton.
1986	July 8, Margot Einstein dies in Princeton.

Credo: “What I Believe”

Einstein conjoined politics and ethics on numerous occasions, but never more poignantly than in “What I Believe.” This essay was first published in 1930 as one in a series of “Living Philosophies” in the journal *Forum and Century*. Because this credo describes Einstein’s beliefs in his own words, we present it here in the full original text, which differs significantly from the version that appeared in the edited collection of Einstein’s essays in *Ideas and Opinions*.

“What I Believe”

Strange is our situation here upon earth. Each of us comes for a short visit, not knowing why, yet sometimes seeming to divine a purpose.

From the standpoint of daily life, however, there is one thing we do know: that man is here for the sake of other men—above all for those upon whose smiles and well-being our own happiness depends, and also for the countless unknown souls with whose fate we are connected by a bond of sympathy. Many times a day I realize how much my own outer and inner life is built upon the labors of my fellow men, both living and dead, and how earnestly I must exert myself in order to give in return as much as I have received. My peace of mind is often troubled by the depressing sense that I have borrowed too heavily from the work of other men.

I do not believe we can have any freedom at all in the philosophical sense, for we act not only under external compulsion but also by inner necessity. Schopenhauer’s saying—“A man can surely do what he wills to do, but he cannot determine what he wills”—impressed itself upon me in youth and has always consoled me when I have witnessed or suffered life’s hardships. This conviction is a perpetual breeder of tolerance, for it does not allow us to take ourselves or others too seriously; it makes rather for a sense of humor.

To ponder interminably over the reason for one’s own existence or the meaning of life in general seems to me, from an objective point of view, to be sheer folly. And yet everyone holds certain ideals by which he guides his aspiration and his judgment. The ideals which have always shone before me and filled me with the joy of living are goodness, beauty, and truth. To make a goal of comfort or happiness has never appealed to me; a system of ethics built on this basis would be sufficient only for a herd of cattle.

Without the sense of collaborating with like-minded beings in the pursuit of the ever unattainable in art and scientific research, my life would have been empty. Ever since childhood I have scorned the commonplace limits so often set upon human ambition. Possessions, outward success, publicity, luxury—to me these have always been contemptible. I believe that a simple and unassuming manner of life is best for everyone, best both for the body and the mind.

My passionate interest in social justice and social responsibility has always stood in curious contrast to a marked lack of desire for direct association with men and women. I am a horse for single harness, not cut out for tandem or teamwork. I have never belonged wholeheartedly to country or state, to my circle of friends, or even to my own family. These ties have always been accompanied by a vague aloofness, and the wish to withdraw into myself increases with the years.

Such isolation is sometimes bitter, but I do not regret being cut off from the understanding and sympathy of other men. I lose something by it, to be sure, but I am compensated for it in being rendered independent of the customs, opinions, and prejudices of others, and am not tempted to rest my peace of mind upon such shifting foundations.

My political ideal is democracy. Everyone should be respected as an individual, but no one idolized. It is an irony of fate that I should have been showered with so much uncalled-for and unmerited admiration and esteem.

Perhaps this adulation springs from the unfulfilled wish of the multitude to comprehend the few ideas which I, with my weak powers, have advanced.

Full well do I know that in order to attain any definite goal it is imperative that one person should do the thinking and commanding and carry most of the responsibility. But those who are led should not be driven, and they should be allowed to choose their leader. It seems to me that the distinctions separating the social classes are false; in the last analysis they rest on force. I am convinced that degeneracy follows every autocratic system of violence, for violence inevitably attracts moral inferiors. Time has proved that illustrious tyrants are succeeded by scoundrels.

For this reason I have always been passionately opposed to such regimes as exist in Russia and Italy today. The thing which has discredited the European forms of democracy is not the basic theory of democracy itself, which some say is at fault, but the instability of our political leadership, as well as the impersonal character of party alignments.

I believe that you in the United States have hit upon the right idea. You choose a President for a reasonable length of time and give him enough power to acquit himself properly of his responsibilities. In the German Government, on the other hand, I like the state's more extensive care of the individual when he is ill or unemployed. What is truly valuable in our bustle of life is not the nation, I should say, but the creative and impressionable individuality, the personality—he who produces the noble and sublime while the common herd remains dull in thought and insensible in feeling.

This subject brings me to that vilest offspring of the herd mind—the odious militia. The man who enjoys marching in line and file to the strains of music falls below my contempt; he received his great brain by mistake—the spinal cord would have been amply sufficient. This heroism at command, this senseless violence, this accursed bombast of patriotism—how intensely I despise them! War is low and despicable, and I had rather be smitten to shreds [sic] than participate in such doings.

Such a stain on humanity should be erased without delay. I think well enough of human nature to believe that it would have been wiped out long ago had not the common sense of nations been systematically corrupted through school and press for business and political reasons.

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed. This insight into the mystery of life, coupled though it be with fear, has also given rise to religion. To know that what is impenetrable to us really exists, manifesting itself as the highest wisdom and the most radiant beauty which our dull faculties can comprehend only in their most primitive forms—this knowledge, this feeling, is at the center of true religiousness. In this sense, and in this sense only, I belong in the ranks of devoutly religious men.

I cannot imagine a God who rewards and punishes the objects of his creation, whose purposes are modeled after our own—a God, in short, who is but a reflection of human frailty. Neither can I believe that the individual survives the death of his body, although feeble souls harbor such thoughts through fear or ridiculous egotism. It is enough for me to contemplate the mystery of conscious life perpetuating itself through all eternity, to reflect upon the marvelous structure of the universe which we can dimly perceive, and to try humbly to comprehend even an infinitesimal part of the intelligence manifested in nature.

*Source: Originally published in *Forum and Century* 84, no. 4 (October 1930): 193–194. Reprinted in Rowe and Schulmann, *Einstein on Politics*, pp. 226–230. Reprinted courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel.*

Part I

The Personal and Family Spheres

A.a.
L

Geburtsurkunde.

Nr. 224

Wien am 15. März 1879.

Vor dem unterzeichneten Standesbeamten erschien heute, der
 Persönlichkeit nach _____
 _____, kannt,
 der Herrmann Hermann Einstein
 wohnhaft zu Wien Aufseßmarkt 3. 16 185
 jüdische Religion, und zeigte an, daß von der
 Frl. Einstein Hermann Hoch, jüdisch,
 _____ jüdische Religion,
 wohnhaft zu _____
 zu Wien in jüdischer Wohnung _____
 am _____ ten _____ des Jahres
 tausend acht hundert _____ zig und _____
 um _____ Uhr ein Kind männlichen
 Geschlechts geboren worden sei, welches _____
 Vornamen
 Albert erhalten habe.

A. Einstein Archiv
29-145

FIGURE 1. Birth certificate. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)

Vital Information: Certificates in Facsimile

Below we present samples of important extant facsimile documents relating to Einstein's life. Translations or further information can be found in the cited cross-references.

Fig. 1. Birth Certificate. See also Birth Information and Family, p. 9

© The Hebrew University of Jerusalem © האוניברסיטה העברית בירושלים

Vorgelesen, genehmigt und *unterschieden* :
Gottmann Einstein

Der Standesbeamte.
Gottmann

Daß vorstehender Auszug mit dem Geburts-Haupt-Register des Standesamts zu
Wien am 1. Jan 1915
 gleichlautend ist, wird hiermit bestätigt.
Wien am *1. Jan* *1915*

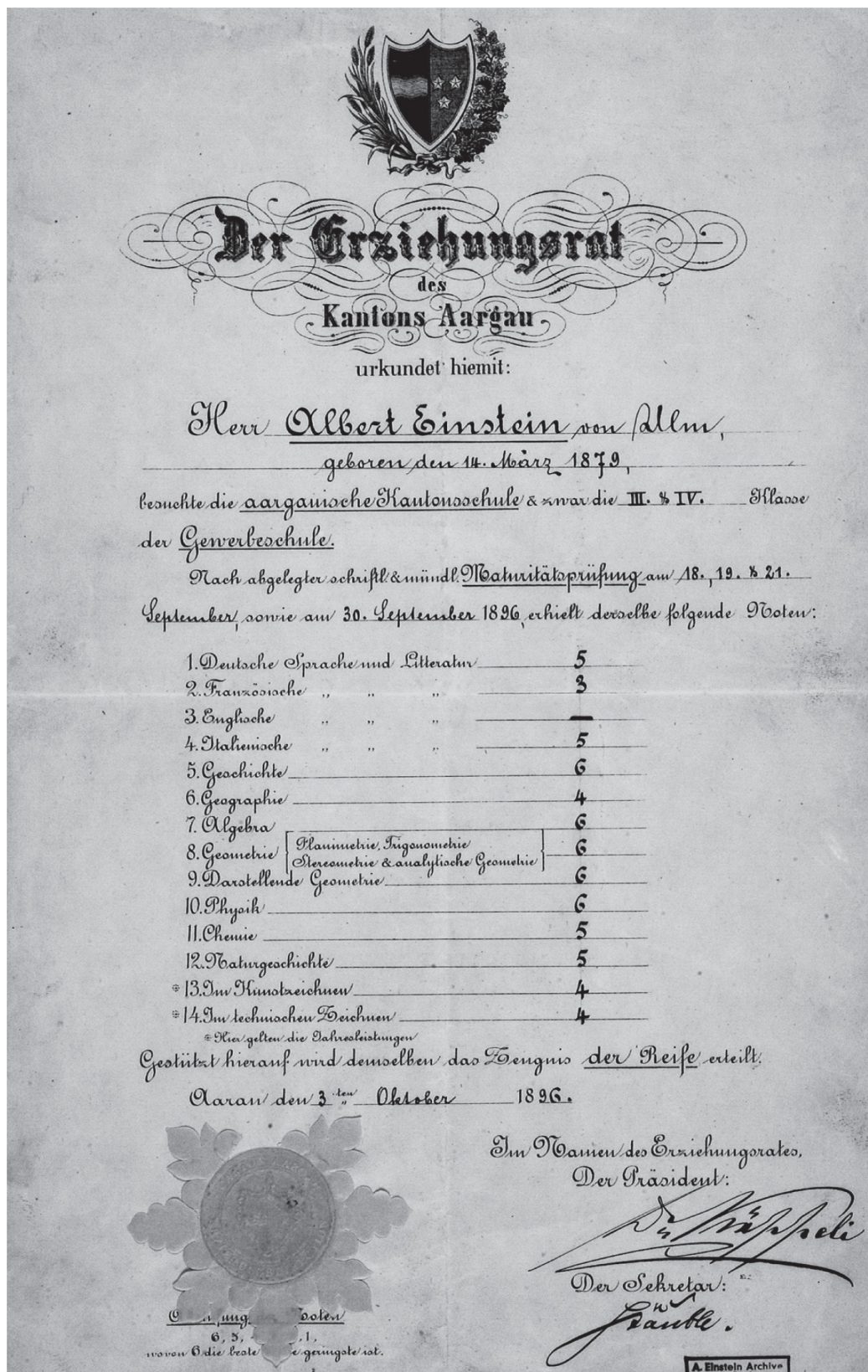
Der Standesbeamte.
Nick

(Siegel.)

*Geheiß für
 Mutter kiste
 1/2 Kant*

A. Einstein Archive
 24-145

Fig. 2. School Report Card. See also Education and Schools Attended, pp. 28–30

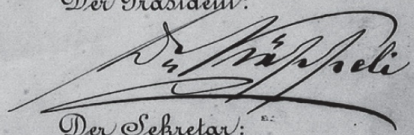
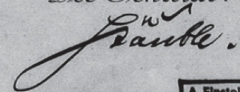



Der Erziehungsrat
 des
Kantons Aargau
 urkundet hiemit:

Herr Albert Einstein von Aem,
 geboren den 14. März 1879,
 besuchte die aargauische Kantonschule & zwar die III. & IV. Klasse
 der Gewerbeschule.
 Nach abgelegter schriftl. & mündl. Naturfächprüfung am 18., 19. & 21.
September, sowie am 30. September 1896, erhielt derselbe folgende Noten:

1. Deutsche Sprache und Literatur	5
2. Französische „ „ „	3
3. Englische „ „ „	—
4. Italienische „ „ „	5
5. Geschichte	6
6. Geographie	4
7. Algebra	6
8. Geometrie	6
9. Darstellende Geometrie	6
10. Physik	6
11. Chemie	5
12. Naturgeschichte	5
13. Im Kunstzeichnen	4
14. Im technischen Zeichnen	4

Gestützt hierauf wird demselben das Zeugnis der Reife erteilt.
 Aarau den 3. ten Oktober 1896.

Im Namen des Erziehungsrates,
 Der Präsident:

 Der Sekretar:



 C. n. ung. Noten
 6, 5, 4, 3, 2, 1
 davon 6 die beste, 1 die geringste ist.

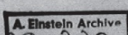


FIGURE 2. School report card. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)

Fig. 3. *Doctoral Certificate*. See also [Part II](#), Doctoral Dissertation



FIGURE 3. Doctoral certificate. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)

Fig. 4. Nobel Prize Certificate. See also [Part II](#), Nobel Prize



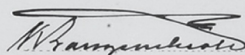
FIGURE 4. Nobel Prize certificate. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)



ALBERT EINSTEIN

för hans förtjänster om den teoretiska fysiken / särskilt hans upptäckt av lagen för den fotoelektriska effekten.

Stockholm den 10 December 1922



Kgl. Vet. Ak:s Præs.

Chr. Aurivillius

Kgl. Vet. Ak:s Sekreterare



Fig. 5. U.S. Naturalization Certificate. See also Citizenships and Immigration to the United States, pp. 22–26

THE UNITED STATES OF AMERICA

ORIGINAL
TO BE GIVEN TO
THE PERSON NATURALIZED

CERTIFICATE OF NATURALIZATION

No. 5013865

Petition No. 4009

Personal description of holder as of date of naturalization: Age 61 years, sex Male, color White, complexion Medium, color of eyes Brown, color of hair Grey, height 5 feet 7 inches, weight 175 pounds, visible distinctive marks None

Marital status Widower former nationality German

I certify that the description above given is true, and that the photograph affixed hereto is a likeness of me.

Albert Einstein
(Complete and true signature of holder)

United States of America }
District of New Jersey } S.S.:
Be it known that **ALBERT EINSTEIN**
then residing at 112 Mercer St., Princeton, New Jersey
having petitioned to be admitted a citizen of the United States of America, and at
a term of the DISTRICT Court of THE UNITED STATES
Trenton, New Jersey held pursuant to law at
October 1st 1940
the court having found that the petitioner intends to reside permanently in the United States, had in all respects complied with the Naturalization Laws of the United States in such case applicable, and was entitled to be so admitted, the court thereupon ordered that the petitioner be admitted as a citizen of the United States of America.
In testimony whereof the seal of the court is hereunto affixed this 1st day of October in the year of our Lord nineteen hundred and forty and of our Independence the one hundred and sixty-fifth.

Benjamin F. Havens
Clerk of the U. S. District Court.
By *Isabel R. Fria* Deputy Clerk.

DEPARTMENT OF LABOR

"This is a personal document and it is a breach of the U. S. Code (and punishable as such) to copy, print, photograph, or otherwise illegally use it."
See other side

29 151

FIGURE 5. U.S. Naturalization certificate. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)

Fig. 6. Death Certificate. See also Death, pp. 122–132

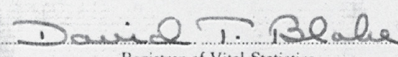
NAME OF DECEASED		PLACE OF DEATH		DATE OF DEATH	
Albert Einstein		Princeton Hospital		April 18, 1955	
SOCIAL SECURITY NUMBER	SEX	COLOR	MARITAL CONDITION	DATE OF BIRTH	AGE
	Male	White	Widower	March 14, 1879	YRS MOS DAYS 76 1 4
PLACE OF BIRTH		CAUSE OF DEATH			
Ulm, Germany		Rupture of Arteriosclerotic Aneurysm of Abdominal Aorta.			
SUPPLEMENTAL INFORMATION IF DEATH WAS DUE TO EXTERNAL CAUSES					
DATE OF OCCURRENCE					
SPECIFY					
WHERE DID INJURY OCCUR?					
CITY OR TOWN COUNTY STATE					
DID INJURY OCCUR IN OR ABOUT HOME, ON FARM, IN INDUSTRIAL PLACE, IN PUBLIC PLACE?					
SPECIFY TYPE OF PLACE					
WHILE AT WORK? MEANS OF INJURY					
NAME OF PERSON WHO CERTIFIED CAUSE OF DEATH			ADDRESS		
Guy K. Dean, Jr., M. D.			Plainsboro, N. J.		
					
 Registrar of Vital Statistics Borough Hall, Princeton, N. J. Address					
April 26, 1955 Date of Issue					

FIGURE 6. Death certificate. (Courtesy Mercer County Courts)

Birth Information

(As given on Birth Certificate, [fig. 1](#), pp. 2–3)

Date of Birth: March 14, 1879, at 11:30 in the morning, a male child, first name of Albert

Place of Birth: Parents' apartment, Bahnhofstrasse B, No. 135, Ulm, Württemberg [Germany]

Parents: Pauline née Koch, a homemaker; Hermann Einstein, a merchant

Parents' Religion: Jewish

Signed by: Hermann Einstein

Archives

(See also Einstein Papers Project and *The Collected Papers of Albert Einstein*, below)

When, in March 1933, Einstein did not return to Germany after the Nazis came to power, his stepdaughter Ilse, with the help of her husband, Rudolf Kayser, and her sister, Margot, packed up his papers in the Berlin residence along with some furniture and other belongings. Rudolf also bundled together some papers at the Einsteins' summer home in Caputh. Through connections with the French ambassador to Germany, André François-Poncet, the Kayzers were able to remove these portions of Einstein's literary estate to France via sealed diplomatic pouch. From there they were shipped to the Institute for Advanced Study in Princeton, New Jersey, where Einstein took up residence in autumn 1933 (see Fölsing, *Albert Einstein*, p. 666). These papers and files constituted the earliest form of what later became the Einstein Archives.

In accord with Einstein's Last Will and Testament (*see* Death, *below*), his literary estate was bequeathed to the Hebrew University of Jerusalem (HUJI). The will stipulated that the files were to be transferred to the university from the Institute after the deaths of Margot Einstein and Helen Dukas (*see* sec. 13E of the will). Enriched by additional originals, copies, and transcriptions, this literary estate became the foundation of the Einstein Archives.

After Einstein's death in 1955, Dukas, later with the help of Gerald Holton of Harvard University, began a systematic organization of Einstein's literary legacy. In the meantime, Otto Nathan, the executor of Einstein's estate, launched a campaign to acquire new material for the archive, also with the help of Dukas and Holton. One of the goals of their project was to prepare the correspondence, writings, and documents for eventual publication by Princeton University Press (PUP) as *The Collected Papers of Albert Einstein*. PUP established an advisory board in the 1970s to jumpstart the ambitious project.

After Dukas's death in early 1982, the archive of original documents was moved to Jerusalem late that year. Dukas had been Einstein's longtime secretary, and after his death, she had become not only a literary trustee but also the first archivist of his papers. In Jerusalem, the first archivist/curator was Manfred Waserman (1988–1989), followed by Ze'ev Rosenkranz (1989–2003), and Roni Grosz (2004 to the present). The archives were shipped from Princeton to the Jewish National and University Library, administratively a part of the HUJI. They are now administered directly by the HUJI's Library Authority.

Today the archives consist of approximately 80,000 items, a sharp increase from the 10,000 documents estimated in 1978 and 42,000 estimated in 1980. The 80,000 figure includes not only Einstein's correspondence, writings, and documents, but also copies, transcriptions, translations, and third-party documents that are invaluable in providing context and preparing annotations. The number also reflects an active and continual search for new materials. As John Stachel, the founding editor of *The Collected Papers of Albert Einstein*, noted in his 1980 guide to the duplicate archive that is now located at Caltech, "The Archive itself is a changing thing. Documents are added and sometimes transferred from one place to another. Annotations may be added, changed, or moved." Einstein's diaries, photos, medals, citations, music collection, and books from his personal library are stored in Jerusalem as well, making this the richest of scientific archives.

Duplicate archives for use by scholars have been established at the libraries of Boston University, the California Institute of Technology in Pasadena, the Federal Institute of Technology (ETH) in Zurich, and Princeton University in New Jersey. Smaller collections can be accessed in various institutes, colleges, and national archives, to which private parties have donated personal papers that include Einstein correspondence and photographs. Among these are Brandeis University (The Albert Einstein Collection); the Leo Baeck Institute in New York City, particularly useful for its photographs; Vassar College in Poughkeepsie, New York (Otto Nathan Papers); and the Prussian State Library in Berlin. The Library of Congress in Washington, DC, also has Einstein-related documents and photographs.

Because Helen Dukas and Otto Nathan were the principal figures in establishing the archives, we have placed their biographical information in this section.

Helen Dukas

Helene Dukas, later known as Helen or Helena Dukas, was born on October 17, 1896, in Freiburg im Breisgau, Germany, to Leopold and Hannchen Dukas. She was one of seven children. Following the premature death of her mother in 1909, she dropped out of high school to care for her siblings. She later became a kindergarten teacher in Munich and in 1923 moved to Berlin to work as a secretary for a publisher. When the small publishing firm was liquidated five years later, Dukas looked for another job. Her sister Rosa, a friend of Elsa Einstein's, had heard that Einstein needed a new private secretary because Ilse Einstein, his first full-time secretary, had married Rudolf Kayser and chose to stop working for her stepfather. Rosa alerted Dukas to the open position. After Einstein had employed several temporary secretaries, including Siegfried Jacoby and Edwin Sicradz, Dukas began work in April 1928 as Einstein's secretary, a position she held until the physicist's death.

Helen Dukas was not a relative of Einstein's, but everyone treated her like a family member. She became an enormously important person in Einstein's life and, after immigrating to the United States, lived in his house with other family members, even after Einstein's death, for the rest of her life. She never married.

Dukas arrived in Princeton in October 1933 with Einstein and his second wife, Elsa. After Elsa's death in late 1936, Dukas became housekeeper in the Mercer Street home in addition to carrying out her duties as secretary. On October 1, 1940, she took the American oath of citizenship in nearby Trenton, New Jersey, together with Einstein and his stepdaughter Margot.

Dukas was known for being intelligent, modest, shy, and passionately loyal to Einstein. She was fiercer about protecting his privacy than even Einstein himself. This trait prompted Einstein to nickname her "my Cerberus," after the hound in Greek and Roman mythology that guarded the entrance to the underworld. Over time, this vigilance and buffering became partly responsible for much of the Einstein mythology. There is no evidence the two ever had a romantic relationship. As if trying to dissuade any rumors, she respectfully referred to him as "Herr Professor" during his lifetime and "the professor" after his death, never as "Albert"—at least in public and in writing. In his last will of 1950, Einstein appointed Dukas, along with his friend Otto Nathan, as co-trustee of his literary estate. The will also stipulated that his personal effects and a sizeable portion of his financial assets be left to her. (*See* Death, "Last Will and Testament.")

After Einstein's death in 1955, Dukas continued to live in the home on Mercer Street with Margot Einstein. She devoted herself to organizing a formal archive of Einstein's considerable writings and correspondence, a task she undertook first in an office in the basement of Fuld Hall at the Institute and later in a small office on the third floor. She worked faithfully and diligently on the files, adding short notes and cross-references to many of the documents she had filed. Moreover, she typed up thousands of transcriptions, mostly of Einstein-authored letters. In addition, she and Einstein's former assistant Banesh Hoffmann, who became a mathematics professor at Queens College in New York, published two books, *Albert Einstein, Creator and Rebel* and *Einstein, the Human Side*.

Dukas continued to come to the office in an Institute shuttle several times a week until her death on February 9, 1982, the result of a ruptured stomach ulcer, at age eighty-five. During her memorial service on February 12 at the Jewish Center in Princeton, Otto Nathan, who had known her for forty-eight years and was close to her for the final twenty-seven, tearfully proclaimed, "When Helen closed her eyes for the last time three days ago, Einstein died a second time. No one was closer to him, no one more dedicated to him. Her purpose in life was to serve Einstein.... She was excited about every new item that came into the archive, as if a part of Einstein himself had returned.... No illustrious scientist could ever duplicate the work she has done." (From Alice Calaprice's notes of the service; *see also* the *New York Times's* obituary.) She left her various assets mostly to her sisters and nieces, to Hebrew University of Jerusalem, and to Margot Einstein. She appointed Otto Nathan as the executor of her estate and bequeathed to him a signed, silver-framed photograph of Einstein. (*See* Einstein Archives 74-628 for a copy of her will.)

Otto Nathan

Otto Nathan was born on July 15, 1893, in Bingen, Germany. An economist, he served as an adviser to the Prussian government during the Weimar Republic from 1920 to 1933 and left Germany after Hitler's rise to power. After immigrating to the United States, he taught at several universities on the East Coast, including Princeton University, Vassar College, and Howard University, and published two books on Nazi economics. With Heinz Norden, he coauthored *Einstein on Peace* (1960).

Einstein and Otto Nathan met in Princeton in the mid-1930s, shortly after both established residence there. They quickly developed a trusting friendship that lasted until Einstein's death. Einstein appointed his old friend as sole executor and a co-trustee of the Einstein estate. With the help of Helen Dukas, Nathan dedicated himself to preserving for posterity Einstein's established legacy as a secular saint. For years, researchers had tried to construct a more realistic portrait of Einstein but were thwarted by the considerable lengths to which Nathan and Dukas went to avoid sharing information that might be damaging to the physicist's established reputation.

Nathan died in New York City on January 27, 1987, at the age of ninety-three, five years after Dukas. He bequeathed his papers to Vassar College and to HUJI.

Awards, Honorary Degrees, and Honorary Memberships in Foreign Societies

Helen Dukas prepared an incomplete list of awards and honors for the Einstein Archives (Einstein Archives 30-105; *see also* Reel 65 in the archives). She noted that the citations themselves were left in German and that her compilation was likely to be incomplete. However, the archives have since been updated, and we were able to verify all listed honorary degrees with the institutions themselves or with certificates in the archives, thereby adding many previously omitted entries to Dukas's original short list. (Numbers in brackets are archival numbers; *CPAE* stands for *The Collected Papers of Albert Einstein*.)

Awards, Medals, and Miscellaneous Honors

1918	Vahlbruch Prize, University of Göttingen [<i>CPAE</i> 8:699n.13]
1918	Müller Foundation honorary prize (Germany) [30-115]
1920	Barnard Medal, Columbia University, for period ending July 17, 1919 (USA) [30-129, 65-012]
1921	Freedom of the City, and Freedom of the State, New York [92-117]; Freedom of the City, New Haven, Connecticut [<i>CPAE</i> 12:453]—while on his first visit to the United States
1921	Nobel Prize in Physics (awarded in 1922) [65-020.3, 85-125]
1921	Election to Royal Society, London [76-427]
1922	Matteucci Gold Medal, Italian Society of Science [30-157, 158]
1923	Diploma of the Golden Book, Jewish National Fund, Jerusalem [65-022]
1923	First “Freedom of the City” award, Tel Aviv (Palestine) [30-170]
1923	Order Pour le Mérite for Science and the Arts (Peace Class) (Germany) [65-075]. Einstein renounced it in 1933.
1924	Einstein Tower, a solar observatory, in Potsdam, near Berlin, completed
1925	Copley Medal, Royal Society (UK) [121-326]
1925	Jewish-Hispanic Congregation of Buenos Aires, medal [65-077]
1926	Gold Medal, Royal Astronomical Society, London [30-214, 79-385]. Also chosen as awardee in 1919 but not confirmed by membership (<i>see Part II</i> , Colleagues, “Arthur Stanley Eddington”) [87-397].
1926	Medal of the Academy of Athens (Greece) [65-080]. Einstein's letter of acceptance is dated 1933.
1929	Planck Medal (Germany). First Planck Medal, shared with Planck himself [19-341].
1930	Key to City of New York, upon his second visit [<i>New York Times</i> , Dec. 14, 1930, p. 1]
1931	French Committee for the Protection of Intellectuals, medal [65-087]
1931	Janssen Medal of the French Astronomical Society, Paris [65-085, 30-255]
1933	Community Church of New York, medal for distinguished religious service [65-089, 69-614]
1935	Franklin Medal, Franklin Institute, Philadelphia [65-056, 88-841 (photo)]
1940	Phi Epsilon Pi National Service Award [88-218]
1947	Foreign Press Award [28-782, 65-113]
1947	Jewish War Veterans of the USA, New York, certificate of honor [65-067]
1947	World Federalist News Award [<i>see</i> Nathan and Norden, <i>Einstein on Peace</i> , p. 404]

1948	One World Award [88-623]
1950	Teachers Union Award, for distinguished service in the cause of education [87-458]
1953	Decalogue Society of Lawyers, merit award [88-518]
1953	Honorary presidency of Hebrew University in Jerusalem [76-487]
1953	Lord and Taylor Award for “intellectual adventuring,” “given to those with a creative and nonorthodox approach to life” [28-979, 72-978, 90-074]
1955	The chemical element 99 was named einsteinium (fig. 7)
1979	Monumental bronze statue unveiled on the grounds of the National Academy of Sciences, Washington, DC
1990	Name added to the Walhalla Memorial for “laudable and distinguished Germans,” near Regensburg, Bavaria (Germany)
1999	<i>Time</i> magazine’s “Person of the Century”
2008	Inaugural inductee into New Jersey Hall of Fame, with Thomas Edison and Clara Barton

Honorary Degrees (*Doctor honoris causa*)

1909	University of Geneva (Switzerland) [30-106 to 109]
1919	University of Rostock (Germany), honorary doctor of medicine [65-008]
1921	University of Manchester (England) [32-628]
1921	Princeton University (USA) [65-015, 84-957]
1922	University of Buenos Aires (Argentina) [30-165, 65-019]
1923	University of Madrid (Universidad Central) (Spain) [65-023.1]



FIGURE 7. The element einsteinium. Einsteinium is a synthetic element with atomic number 99. The only element named for a person with a lower atomic number is curium, named for Marie Curie. The element was first observed in the debris of nuclear explosions. It is so radioactive that in this image the quartz crystal of the container next to the element itself is radioactive and glowing brightly. It is one of the heaviest elements to exist in macroscopic quantities. (Oak Ridge National Laboratory and Wikimedia Commons)

1925	Republic of Brazil, Faculty of Philosophy [65-038]
1925	University of Uruguay, Montevideo, "honorary professor" [65-036]
1929	University of Paris (Sorbonne) [65-049, 120-194]
1930	University of Cambridge (England) [9-299, 30-247]
1930	Federal Institute of Technology (ETH) (Switzerland) [einstein-website.de]
1931	Oxford University (England) [120-221]
1933	Free University of Brussels, Faculty of Sciences (Belgium) [confirmed by Faculty of Sciences 6/24/11]
1933	University of Glasgow (Scotland) [122-538]
1933	University of Pennsylvania (USA) [91-776]
1934	Yeshiva College (now University) (USA) [28-287, 93-637]
1935	Harvard University (USA) [82-484]
1936	Regents of the University of the State of New York [confirmed by Regents 6/30/11]
1936	University of London (England) [65-060]

1946	Lincoln University (USA) [65-066]
1949	Hebrew University of Jerusalem (Israel) [28-855, 65-058]
1951	University of San Marcos (Peru) [30-308, 60-415]
1954	Technion, Haifa (Israel) [28-1058, 69-714]

Sampling of Honorary Memberships in Foreign Academies of Sciences and Societies (while not a resident of that city or country)

1913	Prussian Academy of Sciences, while still in Switzerland (regular membership)
1914	German Physical Society, before moving to Berlin (regular membership)
1915	Royal Society of Göttingen, corresponding member [65-005]
1920	Royal Danish Academy of Sciences, Copenhagen [30-126, 65-011]
1920	Royal Netherlands Academy of Sciences, corresponding member, extraordinary fellow [30-127]
1921	Association of Engineers and Architects of Spain, honorary member [30-176]
1921	Bologna Academy of Sciences (Italy), corresponding member [9-229, 65-013]
1921	Gothenburg Society of Sciences and Arts, Sweden [65-016]
1922	Institución Argentino-Germana [CPAE, Vol. 13, Chronology]
1922	Imperial Japanese Academy of Sciences [CPAE, Vol. 13, Chronology]
1922	National Academy of Sciences (USA), foreign associate [30-147, 65-017]
1922	Royal Society of Science, Uppsala, Sweden [65-018]
1922	Russian Academy of Sciences [30-183, 65-020.2]. Curiously, Einstein's letter of acceptance is dated 1926 [80-020]. <i>See also</i> 1927 for USSR.
1923	Academy of Sciences: Exact, Physical/Chemical, and Natural, of Saragossa (Spain), corresponding member [65-024]
1923	Association of Engineers and Architects, "Erez Israel," stating that Einstein is "the glory of our people" [65-021]
1923	German Medical Science Society of Prague, honorary member [65-025]
1923	Göttingen Academy of Sciences (Germany), corresponding member [65-026]
1923	London Mathematical Society [65-028]
1923	Royal Academy of Sciences: Exact, Physical, and Natural (Madrid, Spain), corresponding member [65-023]
1923	Royal Academy of Sciences and Arts, Barcelona (Spain), corresponding member [121-122]
1924	American Academy of Arts and Sciences (Boston, USA) [65-029]
1924	Society of Physics Research, Athens (Greece) [65-030]
1925	Academy of Exact, Physical, and Natural Sciences, Buenos Aires (Argentina) [65-033]
1925	Academy of Sciences, Rio de Janeiro (Brazil) [65-037]
1925	Argentine Scientific Society, Physical-Mathematical-Natural Sciences, Buenos Aires [65-033]
1925	Ezrahi Hospital, Buenos Aires, honorary member [65-031]
1925	National University of La Plata, Argentina [65-034]
1925,	Polytechnic Association of Uruguay [65-039]
1926	Royal Philosophical Society of Glasgow [65-041.1]
1927	USSR Academy of Sciences, Leningrad [30-221, 120-602]
1928	Royal Irish Academy [30-230, 65-045]
1928	Royal Swedish Academy of Science [65-046]
1930	American Philosophical Society, Philadelphia [65-051]
1931	American Physical Society [30-254]

1931	Royal Academy of Sciences and Art, Belgium, Science Section [65-053]
1933	French Academy of Sciences, Paris [unable to verify]
1933	Academy of Sciences, Athens [122-531]

We did not find any foreign memberships awarded after Einstein's immigration to America.

Career

List of Years, Job Titles, and Employers

1900	Einstein graduates from the Swiss Federal Polytechnical School in Zurich
1901, Summer	Substitute teacher at the Technical School (a secondary school), Winterthur, Switzerland
1901, September	Tutor at private boarding school, Schaffhausen, Switzerland; begins work as doctoral student, University of Zurich
1902	Technical Expert, Third Class, Swiss Federal Patent Office, Bern, examining patents
1906	Receives doctorate from University of Zurich and becomes Technical Expert, Second Class, at patent office
1908	Unsalaries lecturer (<i>Privatdozent</i>) at University of Bern after submitting a <i>Habilitationsschrift</i> (postdoctoral research paper); does laboratory work with Albert Gockel at University of Fribourg in Switzerland
1909	Extraordinary Professor of Physics, University of Zurich
1911	Professor of Theoretical Physics and Director of the Physics Institute, German University of Prague
1912	Professor of Physics at ETH (Federal Institute of Technology, formerly the Swiss Federal Polytechnical School)
1914	Member of Prussian Academy of Sciences; Professor of Physics, University of Berlin
1917–1933	Director of Kaiser Wilhelm Institute of Physics (KWIP), Berlin, while still teaching at the university; also delivered occasional series of lectures at University of Zurich. Max von Laue became deputy director of KWIP in 1922 and took over Einstein's administrative duties.
1920–1930	Special Professor (<i>bijzonder hoogleraar</i>) of Physics, University of Leyden; made regular visits from Berlin to lecture there
1933–1945	Professor of Physics, School of Mathematics, Institute for Advanced Study, Princeton, New Jersey

Employment History

On entering the Swiss Federal Polytechnical School (later the Federal Institute of Technology, ETH) in Zurich in 1896, Einstein set his sights on becoming a secondary-school teacher in mathematics and physics, graduating in 1900 with good if not exceptional marks. Unable to find long-term teaching contracts, he took a position at the Swiss Federal Patent Office in Bern. Beginning in 1907, he offered poorly attended lectures at the University of Bern as a *Privatdozent* (unsalaried lecturer). His academic breakthrough came two years later, when he was appointed *ausserordentlicher* (extraordinary, akin to an associate) professor at the University of Zurich. When Einstein accepted a full professorship at the German University of Prague, a number of students in Zurich, in a petition of June 23, 1910, protested his departure, praising his ability to present the most difficult problems in theoretical physics in a clear and intelligible manner ("Student Petition," June 23, 1910, *CPAE*, Vol. 5, Doc. 210; Einstein Archives 70-159). Almost immediately after his arrival in Prague, he was wooed by his alma mater to return to Zurich. In assessing his

candidacy for the faculty position at the ETH, a colleague touched on Einstein's teaching abilities, emphasizing that while he was not a good instructor for the lazy auditor, he had a knack for compelling his audience to think along with him (Heinrich Zangger to Ludwig Forrer, October 9, 1911, *CPAE*, Vol. 5, Doc. 291; Einstein Archives 80-044). He returned to the ETH in fall 1912.

Less than two years later, Einstein was appointed a member of the Prussian Academy of Sciences in Berlin. His official duties there did not include teaching, though he felt an obligation to offer courses at the University of Berlin and did so periodically. His dismissal from the Prussian Academy in 1933 effectively ended his teaching career, although he lectured occasionally at Princeton University during the early years of his residency at the Institute for Advanced Study.

Places of Employment

PATENT OFFICE, BERN

The young Einstein's first "real" position was hard won, as shown by his father's concern in the following letter to Wilhelm Ostwald, a physical chemist at the University of Leipzig and future Nobel laureate. The letter was sent from Milan on April 13, 1901:

Please forgive a father who, in the interest of his son, presumes to write to you, esteemed professor.

Let me begin by telling you that my son, Albert Einstein, is 22 years old, studied at the Zurich Polytechnic for 4 years, and last summer passed his final examinations in mathematics and physics with distinction. Since then he has unsuccessfully tried to secure a position as *Assistent* that would allow him to broaden his training in theoretical and experimental physics. All those capable of evaluating his talents have praised him. In any case, I can assure you that he is extraordinarily industrious and diligent and is passionately dedicated to his science.

My son feels very unhappy in his current state of unemployment and is becoming increasingly concerned that he is going off-track with his career and losing touch. Furthermore, he is distressed that he has become a burden for us, since we are people of modest means.

Because my son admires you, highly esteemed professor, above all others who are currently engaged in the field of physics, I have allowed myself to turn to you with the kind request that you read the paper he published in *Annalen der Physik*, and perhaps to write him a few lines of encouragement so he will regain his joy of living and creating.

If it would be possible for you to arrange for him to obtain an *Assistent's* position either now or next fall, my gratitude would be boundless.

Please again excuse my impertinence in writing you these lines, and allow me to note that my son does not know that I have taken this unusual step. [Einstein Archives 71-549]

Ironically—and apparently without his father's knowledge—Einstein had written to Ostwald himself only four weeks earlier. There is no evidence that Ostwald ever replied to either of the Einsteins. Within a year, however, an entry-level position for a patent clerk opened up at the Swiss Federal Patent Office in Bern. Luckily for Einstein, his friend Marcel Grossmann's father knew the director of the office, Friedrich Haller. The elder Grossmann sent a letter of recommendation to Haller on Einstein's behalf. In June 1902, the young physicist received a provisional appointment as technical expert, third class, and in early 1906 he was promoted to expert, second class. In accordance with Swiss patent law, his job required that he examine and review patent applications for efficacy, not novelty. This kind of work apparently gave him abundant time to think about other topics closer to his heart; whether he did so during or after hours is unclear. During his tenure at the patent office, Einstein published his best-known papers, apart from the later work on general relativity. He stayed there until October 1909, while also holding a part-time position as lecturer at the local university.

UNIVERSITY OF BERN

In June 1907, Einstein submitted his dissertation and seventeen papers, including those from the *annus mirabilis*, to the University of Bern in an attempt to obtain a teaching position. The faculty rejected Einstein's petition because he had failed to submit a "specialized investigation." In early January of the following year, he overcame this pedantic objection and submitted a *Habilitationsschrift* (similar to a postdoctoral thesis) on blackbody radiation that was accepted toward the end of February. Almost immediately, he was required to give an inaugural lecture, which he titled "On the Limit of the Validity of Classical Thermodynamics," and presented it to an academic audience on February 27. The thesis and lecture were a significant step in establishing his eligibility for a professorship at the University of Zurich in 1909. In April, he began teaching his first course on the molecular theory of heat while both continuing to work at the patent office and also working at the laboratory of Albert Gockel in Fribourg for two months on the construction of a small induction machine (the so-called *Maschinchen*). He left the university and the patent office in 1909 to accept an associate professorship in Zurich.

UNIVERSITY OF ZURICH

In February 1909, a second teaching position in physics was created at the University of Zurich. Einstein was recommended for it by Alfred Kleiner, who had been his doctoral adviser at the university. It is likely that Kleiner had been grooming Einstein for the position for some time while awaiting the necessary funding (see letters from Alfred Kleiner, January 28, 1908, and February 8, 1908, *CPAE*, Vol. 5, Docs. 78 and 80; Einstein Archives 29-249 and 29-252. See also Schulmann, "Einstein at the Patent Office"). The appointment began in winter semester 1909, that is, in October. The previous July, he had received his first honorary doctorate—from the University of Geneva, and in October, Wilhelm Ostwald, who apparently had ignored Einstein's application to Leipzig back in 1901, nominated Einstein for the Nobel Prize. He would receive several more nominations before receiving the award for 1921 (see [Part II](#), Nobel Prize). He stayed in Zurich until January 1911, when he resigned to accept a position in Prague.

GERMAN UNIVERSITY OF PRAGUE

On January 6, 1911, Emperor Franz Joseph of Austria-Hungary appointed Einstein to the physics chair at the German University of Prague, also known as Charles University. Einstein resigned his position in Zurich and moved his family to Prague in April, when he also became director of the university's Institute of Theoretical Physics. By the fall of that year, Einstein was already approached about positions in Utrecht and at the Federal Institute of Technology (ETH) in Zurich. He accepted an offer from the latter and left Prague the following July.

FEDERAL INSTITUTE OF TECHNOLOGY (ETH)

When Einstein was a student there, the ETH was named the Swiss Federal Polytechnical School. In 1911, it was changed to the Federal Institute of Technology (Eidgenössische Technische Hochschule). At the end of January 1912, at the age of thirty-two and less than twelve years after he had left as an undergraduate, he accepted an appointment there as Professor of Theoretical Physics, gained largely through the efforts of his friend, Heinrich Zangger. Because he still had teaching obligations in Prague, he did not begin teaching at the ETH until October. Besides the usual teaching and research duties, he also assumed various administrative responsibilities, such as serving as an examiner for mathematics students. He stayed at the ETH until 1914.

PRUSSIAN ACADEMY OF SCIENCES, UNIVERSITY OF BERLIN, AND THE KAISER WILHELM INSTITUTE OF PHYSICS

In mid-July 1913, two prominent members of the Prussian Academy of Sciences, Max Planck and Walther Nernst, visited Einstein in Zurich and sounded him out for special membership in the academy. In contrast to regular members, who earned only an annual honorarium, he was offered a handsome salary. In keeping with the two-track

German system in which academies were devoted to research and universities to teaching, Einstein's appointment would emphasize research concerns, though he was free to offer courses at the university. The men also discussed with Einstein the creation of an institute of physics in Berlin, to be established by the Kaiser Wilhelm Society, and invited him to become its director. In November, his membership in the academy was confirmed, and Einstein resigned from his position at the ETH, formally accepting the Berlin offers. He moved to Berlin in spring 1914, but his wife Mileva and their two sons, who had joined him briefly, soon returned to Zurich because of the couple's marital problems.

The establishment of the Kaiser Wilhelm Institute of Physics (KWIP), privately financed by Leopold Koppel, a German banker and entrepreneur, was delayed for three years, until October 1917, because of the outbreak of the First World War. According to an explanatory note that Einstein sent to the Berlin mass-circulation newspaper, *Vossische Zeitung*, on April 1, 1923, the KWIP was fundamentally an organization that funded scientific research in both theoretical and experimental physics and had no physical facilities such as a building or laboratories. The KWIP did not move into a building of its own until 1938, five years after Einstein had left for the United States. Einstein's job as director was to solicit research proposals that the institute would review and either fund or reject. Even though he was contractually not obliged to do so, Einstein chose to teach at the University of Berlin both before and after he became director of the new institute. He held this position until 1933, when he resigned from the Prussian Academy and the Institute after Hitler came to power.

Although Einstein worked mostly in Berlin, he also accepted a visiting lectureship at the University of Leyden, which brought him to the Netherlands regularly for several years beginning in 1920. He had been strongly encouraged to do so by Paul Ehrenfest, H. A. Lorentz, and Heike Kamerlingh Onnes, close colleagues in the Netherlands. In fact, Einstein had been chosen to replace the retired Lorentz as professor of theoretical physics but turned down the offer. Paul Ehrenfest, who was instrumental in attracting Einstein as a regular lecturer until April 1930, succeeded him instead.

Sources: CPAE, Vols. 8–14; Carlo Beenakker, Leyden, personal communication; Dirk van Delft, "Albert Einstein in Leiden," *Physics Today*, April 2006, pp. 57–72.

INSTITUTE FOR ADVANCED STUDY, PRINCETON, NEW JERSEY, USA

Since its formal inception in 1930, the Institute's mission has been to attract the world's best scholars, allow them to work in a harmonious and collegial community of internationally renowned researchers without the burden of teaching undergraduate students, and earn generous salaries while doing so.

From 1933 until 1940, the Institute was given temporary quarters on the Princeton University campus, in Fine Hall, the old mathematics building (now called Jones Hall). Because of this early logistical connection to the university, many outsiders are under the impression that the Institute is a part of the Ivy League institution. In 1940, the Institute's small faculty, including Einstein, moved to a newly built 800-acre campus in a rural and wooded part of Princeton. Einstein retired from the Institute in 1945 but continued to occupy an office in Fuld Hall, the main building, until his death ten years later.

Citizenships and Immigration to the United States

Born in Germany to parents whose families had deep roots there, Einstein was a Württemberg (German) citizen by birth. In 1896, while attending school in Aarau, Switzerland, while his family was living in Italy, Einstein, with his father's approval, resolved to give up his Württemberg citizenship. His intent likely was to avoid mandatory military service in the German army when he turned seventeen. To formalize his decision, he requested his release from German citizenship in late January 1896. He was encouraged in the process by Jost Winteler, with whom he boarded while attending the Aargau Cantonal School and who was openly disdainful of the "religion of might" in Germany.

In 1899, Einstein began to save the money required to apply for Swiss citizenship, which would allow him to seek employment in the Swiss civil service, including teaching positions. After the local police department issued a report attesting to his "good conduct," Einstein also passed the muster of the naturalization commissioners during a personal interview. On February 21, 1901, three weeks before his twenty-second birthday and a week after he paid the citizenship fees, Albert Einstein was declared fit to be a citizen of the municipality and canton of Zurich and, thus automatically, of the Swiss Confederation.

Einstein returned to Germany in 1914 to accept a position as a member of the Prussian Academy of Sciences, as professor of physics at the University of Berlin, and eventually as director of the newly established Kaiser Wilhelm Institute of Physics. Because these were civil service appointments, he was required by law to be a Prussian (German) citizen, a fact of which he was made aware while still in Switzerland. His only condition for accepting the positions was that he be allowed to retain his Swiss citizenship (*see* letter to Heinrich Lüders, March 24, 1923, *CPAE*, Vol. 13, Doc. 454; Einstein Archives 79-362), and this request was honored. In fact, the academy was so eager to grant him membership that it ignored the requirement for him (*see* Grundmann, *The Einstein Dossiers*, pp. 168–174). During the First World War and after, he continued to travel on a Swiss passport.

The academy's perspective changed when Einstein became the recipient of the Nobel Prize in Physics in 1922, retroactively for 1921. Though the prize was awarded to individuals, it was perceived by the public and in official circles as a national honor. Raison d'état demanded that Einstein and his celebrity be linked closely to the Prussian state. After German ambassador Rudolf Nadolny stood in for the absent Einstein at the awards ceremony in Sweden, the envoy requested clarification from his government of possible Swiss citizenship claims on Einstein. The academy responded that, whatever else had happened before, Einstein had taken the civil-service oath of allegiance to Germany and Prussia in July 1920 and March 1921, respectively, thereby unequivocally making him a German citizen. This information was conveyed to Einstein with the assurance that his Swiss citizenship remained unaffected (*see* letter from Heinrich Lüders, February 15, 1923, *CPAE*, Vol. 13, Doc. 431; Einstein Archives 29-179.06). Urged to finally resolve the matter, Einstein met with a ministerial representative, after which he issued the following statement: "The question has been raised at the Academy whether in addition to my Swiss citizenship I also possess Prussian citizenship. At the Academy's request, I had a discussion with Dr. [Otto] von Rottenburg at the Ministry of Culture about this. He was adamant in his opinion that my employment by the Academy was linked to the acquisition of Prussian citizenship, as there are no grounds to the contrary to be found in the records. I raise no objection to this opinion" ("Note on Prussian Citizenship," February 7, 1924, *CPAE*, Vol. 14, Doc. 209; Einstein Archives 79-370). However reluctantly, Einstein had officially acknowledged his Prussian citizenship.

Dual citizenship became an issue again after Hitler's election as German chancellor in January 1933. A month later, upon returning to Europe from his third trip to Pasadena, California, Einstein announced that he would not set foot in Germany again and that he was resigning from the academy. Days before Einstein landed in Belgium, the new German government declared a nationwide boycott of Jewish businesses, and a prominent right-wing newspaper published a defamatory caricature of Einstein as a delusional malingerer who imagined himself to be a Prussian. From Ostend in Belgium, he and Elsa wrote the German Foreign Office, requesting their release from German citizenship.

The reaction of his former colleagues in the Academy to his resignation was a bitter disappointment to Einstein. With the exception of Max von Laue, members did not speak out against the academy's official declaration that Einstein had brought exclusion upon himself by spreading distortions abroad about the new regime. The process of officially releasing him from German citizenship was more complicated and far lengthier than usual, as Einstein's case became a pawn in an internal power struggle between governmental ministries. The Foreign Ministry argued that Einstein had forced the citizenship issue by withdrawing from the academy and that his citizenship should thus be allowed to lapse. The Ministry of the Interior took the harder line that he had to be expelled because of the lies he had told abroad about the Nazi regime. After ten months, the latter won the argument, and in March 1934, almost a year after his initial request, Einstein was once again a Swiss citizen only.

Presumably, the irony was not lost on him that in 1922, when he received the Nobel Prize, the Prussian government had gone to great lengths to ensure that he was a German national, and now, a decade later, it brutally stripped him of that citizenship. In addition, on May 10, 1933, on the very day of the Nazi book burning of “un-German” works, including those of Jewish authors, the Gestapo informed the Einsteins that their financial assets in Germany had been confiscated. Expropriation of their summer house in Caputh and of Einstein’s sailboat followed soon after.

Determined never to live in Germany again following their return from America in March 1933, the Einsteins resettled in Coq sur Mer, Belgium, while Einstein considered a number of appointments in “Princeton, Madrid, Paris, Oxford” (see letter to Paul Langevin, June 4, 1933; Einstein Archives 15-397). Ilse and Rudolf Kayser had meanwhile arranged to have Einstein’s papers from the Berlin apartment and the house in Caputh sent to safety in France by diplomatic pouch.

By September, Einstein had accepted the Princeton appointment. After receiving death threats in Belgium, he and his wife spent their last month in Europe enjoying the protection and hospitality of the British naval commander and politician Oliver Locker-Lampson near his home in Cromer, Norfolk, England. The future archives were shipped to the United States along with other belongings retrieved from the Einsteins’ Berlin apartment (see also Archives). With Helen Dukas and Walther Mayer, the Einsteins boarded the SS *Westmoreland* in Southampton for another long voyage to America, this time, as it turned out, to live there permanently. They arrived in New York Harbor on October 17, and from there traveled to Princeton, New Jersey, where Einstein had accepted an offer from the co-founder of the Institute for Advanced Study, Louis Bamberger. Ilse, Margot, and their husbands remained in Europe. Ilse fell ill and Elsa returned to Europe to be at her bedside; Ilse died in France in 1934. Elsa then sailed back to America once more, this time with Margot, her younger daughter. The widowed Rudolf immigrated a year later. Margot’s husband, Dmitri, eventually came to the United States as well. (See also Family.)

Einstein had entered the United States in 1933 with a visitor’s visa. Under U.S. immigration law at the time, permission to become a citizen could be obtained only through an American consul in a foreign country. In late 1933, however, Congressman F. H. Shoemaker sent a letter to President Franklin D. Roosevelt recommending that he extend U.S. citizenship to Einstein by executive order (December 1, 1933; Einstein Archives 33-128). The following year, it was proposed that Einstein be granted citizenship by an act of Congress, but he declined. Instead, he and his family and Helen Dukas went to Bermuda to apply for citizenship in May 1935 (fig. 8). The American consul on the island hosted a festive dinner in Einstein’s honor and gave his guests legal permission to enter the United States as permanent residents. In 1937, another movement was planned to grant him citizenship more quickly through an Act of Congress (see newspaper account, February 20, 1937; Einstein Archives 93-220). Finally, three years later, in 1940, Einstein, Margot Einstein, and Helen Dukas became citizens through regular channels as they completed the required five-year waiting period and took the oath of allegiance in Trenton, New Jersey (fig. 9). Elsa had died in December 1936, and thus did not have the opportunity to become an American citizen.

TRIPLICATE
(To be given to
declarant)

No. 1442

UNITED STATES OF AMERICA

DECLARATION OF INTENTION

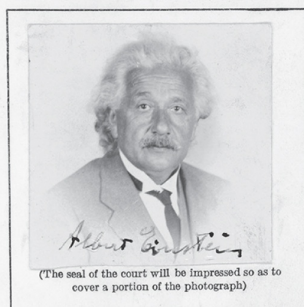
(Invalid for all purposes seven years after the date hereof)

United States of America } In the District Court
District of New Jersey } ss: The United States at Trenton, N. J.

I, Dr. Albert Einstein
now residing at 112 Mercer St., Princeton, N.J.
occupation Professor, aged 56 years, do declare on oath that my personal description is:
Sex Male, color White, complexion Fair, color of eyes Brown
color of hair Grey, height 5 feet 7 inches; weight 175 pounds; visible distinctive marks
none
race Hebrew; nationality German
I was born in Ulm, Germany, on March 14 1879
I am married. The name of my wife Elsa
we were married on April 6th 1917, at Berlin, Germany; she or he was
born at Hachtinger, Germany, on January 18, 1877, entered the United States
at New York, June 2, 1935, for permanent residence therein, and now
resides at with me. I have 2 children, and the name, date and place of birth,
and place of residence of each of said children are as follows: Albert born 5-14-1905 and
Eduard born 6-28-1910 both born and reside in Switzerland

I have not heretofore made a declaration of intention: Number _____, on _____ (Date)
at _____ (City or town)
my last foreign residence was Bermuda, Great Britain
I emigrated to the United States of America from Bermuda, Great Britain
my lawful entry for permanent residence in the United States was at New York, N.Y.
under the name of Albert Einstein, on June 3, 1935
on the vessel SS Queen of Bermuda

I will, before being admitted to citizenship, renounce forever all allegiance and fidelity to any foreign prince, potentate, state, or sovereignty, and particularly, by name, to the prince, potentate, state, or sovereignty of which I may be at the time of admission a citizen or subject; I am not an anarchist; I am not a polygamist nor a believer in the practice of polygamy; and it is my intention in good faith to become a citizen of the United States of America and to reside permanently therein; and I certify that the photograph affixed to the duplicate and triplicate hereof is a likeness of me: So HELP ME GOD.



(The seal of the court will be impressed so as to cover a portion of the photograph)

Subscribed and sworn to before me in the office of the Clerk of said Court, at Trenton, N. J. this 15th day of January anno Domini 1936. Certification No 3-120742 from the Commissioner of Immigration and Naturalization showing the lawful entry of the declarant for permanent residence on the date stated above, has been received by me. The photograph affixed to the duplicate and triplicate hereof is a likeness of the declarant.

George T. Cranmer
Clerk of the U. S. District Court.
By De Haven, Deputy Clerk.

Form 2202-I-A
U. S. DEPARTMENT OF LABOR
IMMIGRATION AND NATURALIZATION SERVICE

14-2623
U. S. GOVERNMENT PRINTING OFFICE: 1932

Nº 5773

FIGURE 8. Citizenship application, "Declaration of Intention." The Einsteins, according to immigration laws at the time, were required to re-enter the United States from a foreign country, and they chose Bermuda, a British Overseas Territory, in June 1935, five years before citizenship was granted. (Wikimedia Commons)

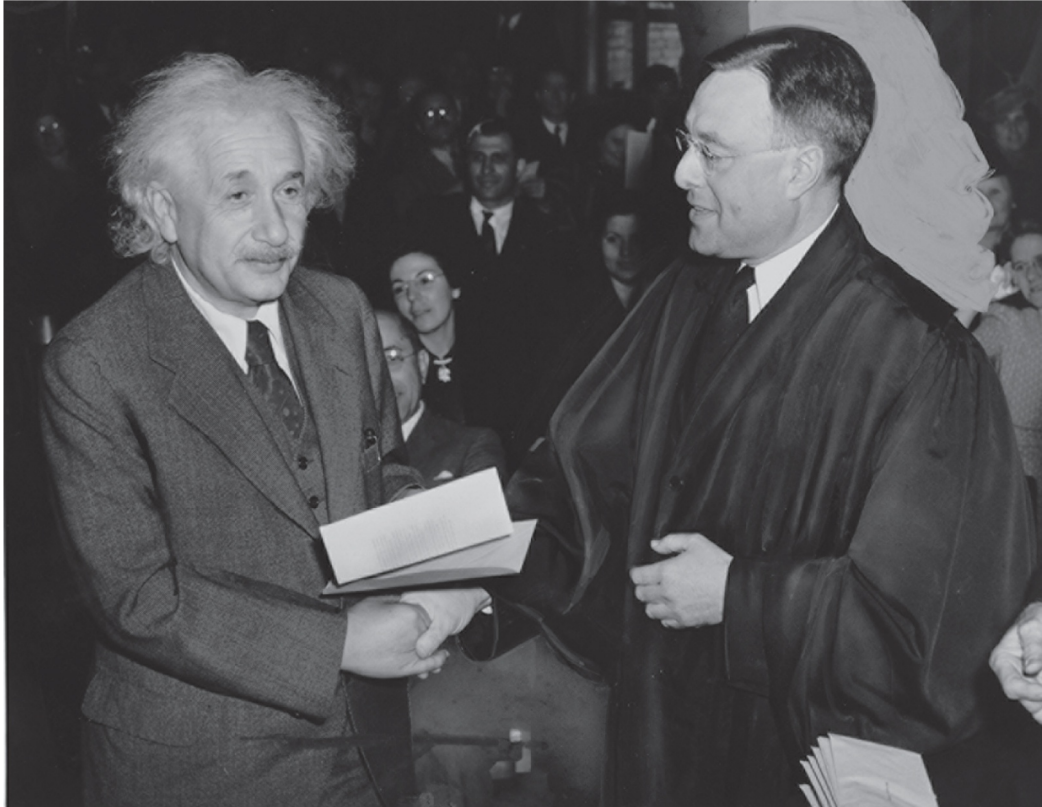


FIGURE 9. Einstein being congratulated by Judge Phillip Forman after taking the oath of U.S. citizenship in Trenton, NJ, on October 1, 1940. (Photo by Al Aumuller, *New York World Telegram & Sun*; Library of Congress)

Domiciles

1879–1880, Ulm
1880–1894, Munich
1895, Milan
1895–1896, Aarau, canton of Aargau, Switzerland
1896–1902, Zurich
1902–1909, Bern
1909–1911, Zurich
1911–1912, Prague
1912–1914, Zurich



MAP 1. Some of the towns and cities within Europe mentioned in this book, in which Einstein and his family lived and to which he traveled for work, conferences, and pleasure. A few major cities are included as reference points.

1914–1933, Berlin; vacation home in Caputh, 1929–1932; winter trips to Pasadena, 1930–1933

1933, Coq sur Mer, Belgium, while fleeing Hitler and before immigrating to the United States

October 1933–April 1955, Princeton, NJ ([fig. 10](#)); summers in Huntington, Long Island, NY; Peconic, Long Island, NY; Saranac Lake, NY; Watch Hill, RI; Old Lyme, CT; Deep Creek Lake, MD.



FIGURE 10. The Einsteins' home on Mercer Street in Princeton, NJ. (Photo by Dmadeo, Wikimedia Commons)

Education and Schools Attended

(See also [Part III](#), Education: Einstein's Views)

Educational Background

As a pupil in Munich, Einstein resisted the rote memorization that characterized the usual school curricula. Instead, he devoured readings that engaged his curiosity, such as Aaron Bernstein's multivolume compendium, *Naturwissenschaftliche Volksbücher* (Natural Science Books for a General Readership). His lack of respect for authority apparently led to disciplinary problems in his Munich *Gymnasium* (secondary school), which he left in midterm as a fifteen-year-old in 1894, though one teacher complimented him on his mathematical abilities (see Kayser, *Albert Einstein: A Biographical Portrait*, pp. 42–43). He completed his secondary-school education in Switzerland, the youngest pupil in a class of fifteen, at the Aargau Cantonal School in the town of Aarau, where he found coursework and teacher attitudes more conducive to instilling the independence of thought he prized ([fig. 11](#)). The school record reflects Einstein's contentment: his grades were consistently excellent in spite of a persistent myth that he was a poor pupil as an adolescent. (See [Myths and Misconceptions](#).)



FIGURE 11. The Aargau Cantonal School in Aarau, Switzerland, which Einstein attended 1895–1896 during his last year of secondary schooling, before attending the Swiss Federal Polytechnical School (ETH). (ETH, Zurich)

In 1895, at the age of sixteen, two years younger than the regular age of admission, Einstein had tried to enter the Swiss Federal Polytechnical School (later ETH) in Zurich but failed the entrance exam, though his marks in physics and mathematics were high. The rector wrote that he needed another year to become more mature and increase his language skills (see Albin Herzog to Gustav Maier, September 25, 1895, *CPAE*, Vol. 1, Doc. 7; Einstein Archives 71-660). Einstein's successful leaving examination from the Aargau Cantonal School granted him automatic admission to the ETH the following year. He graduated with a teaching diploma in 1900 and soon began work toward a doctorate at the University of Zurich (at that time, the Poly did not grant doctorates) while also teaching part time and later working at the patent office. (See *CPAE*, Vol. 1, for Einstein's early education.)

Schools and Universities Attended

Petersschule, Munich, Germany (Catholic primary school), fall 1885–1888

Luitpold Gymnasium, Munich, Germany (secondary school), fall 1888–December 1894

Home study in Milan, January–fall 1895

Aargau Cantonal School, Aarau, Switzerland (secondary school), fall 1895–fall 1896

Swiss Federal Polytechnical School (ETH) (university level), fall 1896–summer 1900

University of Zurich (doctoral work), fall 1900–summer 1905; doctorate conferred, January 1906

University of Bern (*Habilitation*), 1908. A *Habilitation*—a postdoctoral thesis—is required of doctoral recipients in many European countries to prove they are capable of teaching at a university level and conducting independent, high-quality research. It qualifies holders to supervise doctoral students later in their careers. An “inaugural lecture” was also required to demonstrate one's ability to teach.

Einstein Papers Project (EPP) and *The Collected Papers of Albert Einstein* (CPAE)

(See also Archives, *above*; and Death, “Last Will and Testament,” *below*.)

Herbert S. Bailey, the director of Princeton University Press (PUP) during the negotiations in the 1970s and 1980s that eventually led to the publication of the Einstein archives, called the Press’s publishing endeavor “the greatest of its kind in this century.” Its goal was ambitious: to present to the public Einstein’s published and unpublished writings and correspondence, including his personal and scientific correspondence; the scientific, political, and humanitarian writings that had made him famous throughout the world; and his travel diaries, class notes, and vital documents. The volumes would on occasion also include third-party materials that would help document and provide context for Einstein’s thoughts and activities as they played out over his lifetime. The series, to be called *The Collected Papers of Albert Einstein*, was at the time projected to comprise at least twenty volumes and take twenty years to complete. Publication began in late 1985 with the submission of a preliminary manuscript of volume 1 to PUP. At present (2015), approximately thirty years later, the estimates are quite different: the Einstein Papers Project has completed fourteen volumes, and approximately sixteen more are projected to be published before the series is considered complete, most likely before the middle of the century.

When Bailey and the Einstein Papers Advisory Board announced their early predictions, they had estimated that the archive contained about 10,000 documents. The count had more than quadrupled, to 42,000, by the time a computerized index was finished in 1980. Following a continual and successful search for new documents by the editors, the number has almost doubled—to approximately 80,000 items today, though many of them consist of duplicates and various transcriptions, some translations, as well as material necessary for editorial annotations.

Prehistory of the EPP

After Einstein's death in 1955, his literary estate, including the future archive, was entrusted to his friend, the economist Otto Nathan, of New York, and Einstein's longtime secretary and housekeeper, Helen Dukas, as stipulated in sec. 13 of his will. The will designated them as cotrustees (sec. 17), and Nathan was also appointed the sole executor. According to the will, after the deaths of Dukas and Einstein's stepdaughter, Margot, the archive was to be transferred to The Hebrew University of Jerusalem (HUJI). Einstein's stepdaughter, Margot Einstein, though she was not an official co-trustee, was to receive income from the literary estate and had the right to transfer the estate to HUJI if Dukas were to predecease her.

Dukas also became the archivist of the literary estate. She established her archive in the basement of Fuld Hall at Princeton's Institute for Advanced Study, later moving to the third floor of the building. She transferred to her office most, but as it turned out not all, documents that were originally held in Einstein's house on Mercer Street. With the help of Harvard professor Gerald Holton, Dukas organized the archive into a system of folders kept in metal file cabinets, and made almost daily trips to the archive until her death early in 1982 at the age of eighty-five. Until then, only a handful of people had been allowed access to the originals. The "Dukas archive" thus became the foundation for *The Collected Papers of Albert Einstein*. Nathan, meanwhile, had been attending to the complex business matters associated with the estate.

Nathan and Dukas were fiercely protective of the image of Einstein they had helped to create and that largely still prevails today, except for occasional but unsuccessful attempts to create a more sinister image—"father of the atom bomb," "plagiarist," "thief of his wife's ideas," "mathematical incompetent." Both trustees knew that the archive, especially the family correspondence, contained information that was not always consistent with the established image. Therefore, they were painstakingly selective about what should be published, and by whom. With the encouragement of J. Robert Oppenheimer, Bailey, among others, approached Nathan about publishing a collection of Einstein's scientific works, but Nathan insisted that any collection should also include the physicist's other writings. He felt, moreover, that, in the long term, Einstein would be remembered more for his writings on peace than his scientific work and even suggested that Einstein's political writings be published first. Indeed, by 1960, Nathan, together with Heinz Norden, had already published a volume of Einstein's writings on peace.

In 1970, Nathan formally proposed that PUP undertake the publication of a comprehensive series of volumes containing all of Einstein's writings. PUP's trustees approved the project, and the following year, on February 22, 1971, a publishing agreement was signed between PUP and the estate. When the estate was transferred to The Hebrew University in Jerusalem in late 1982, both entities agreed to jointly sponsor and cooperate in the editorial effort, including fund-raising.

In accordance with the agreement, PUP formed an editorial advisory board. Most of the ten inaugural members were scientists and historians of science: Valentin Bargmann, Marshall Claggett, Freeman Dyson, Charles Gillispie, Gerald Holton, Martin J. Klein, Thomas S. Kuhn, Marston Morse, Shmuel Samburski, and John Wheeler. Their primary duties were to select an editor and determine whether the collection would be published in the original languages (primarily German) or in English. The consensus was to publish in the original languages, with editorial notes and other editorial material in English. Later, as a result of negotiations with the National Science Foundation (NSF), which had advocated for an English edition, the decision was made also to provide an adequate, accurate, if not literary, English version as a paperback companion to each volume. The NSF provided seed money for this separate project. The translation volume would contain none of the editorial annotations and other elements of what later came to be known as the "documentary edition."

In 1976, after a complex five-year search, the board recommended hiring John Stachel, a professor of physics on the faculty of Boston University, as the director of the project and founding editor of the series. Stachel accepted the offer.

Early Days

Work began in January 1977, after Stachel had arrived at his new office in Fuld Hall, next to the one occupied by Helen Dukas on the third floor. It soon became clear to Stachel that Einstein did not separate his personal and scientific lives. Stachel's important vision for the project was to embed Einstein's scientific and political writings in a historical-biographical framework, including his extensive correspondence and his working drafts and notebooks that could help readers trace the evolution of Einstein's ideas. In launching the project, Stachel's task was complicated by the fact that only he was allowed access to the original documents. One of his first tasks was to hire assistants in 1977 and 1978 to prepare three computerized indexes: a sequential index organized by archive number, an index of correspondence from and to Einstein, and a chronological index that included both correspondence and writings.

LEGAL PROBLEMS WITH THE ESTATE

After this initial work was almost completed, however, Otto Nathan suddenly expressed dissatisfaction that Princeton and its board of trustees had chosen Stachel as the sole editor. Furthermore, he disapproved of the plan to include the personal information about Einstein that the estate's trustees considered private. Nathan proposed that a group of three equal and specialized co-editors replace Stachel, and that a separate administrator manage the nonscholarly aspects of the project. Bailey, knowing that it had taken five years to find even one editor, disagreed with this approach. He also contended that the project would be better served with only one person in charge, assisted by specialized associate editors to be added as needed. The advisory board agreed to retain Stachel and allowed him to proceed with the project.

Nathan responded by taking legal steps against PUP to stop Stachel from continuing the editorship. A formal ten-day arbitration took place in New York City in 1980, which ruled in PUP's favor. This ruling, however, did not end the dispute. The trustees of the estate—Nathan and now Dukas as well—remained resolute in their belief that Stachel was not the man for the job. They appealed the arbitrator's decision until it reached the highest court in New York State. This court upheld the judgment of the arbitrator, Harold R. Tyler Jr., who deemed that Stachel "is qualified to be the editor."

FUNDING

While the EPP's future was uncertain, it had been difficult not only to staff the project with assistant and associate editors who would complement Stachel's expertise, but also to obtain the necessary funding for such a long-term undertaking. Almost at the last moment, the publishing executive Harold W. McGraw, president of the board of trustees of PUP, came to the rescue with a \$1 million personal gift to endow the salary of the editor for the duration of the project. The Alfred P. Sloan Foundation followed with an emergency grant to fund operating expenses, and Professors Res Jost and Konrad Osterwalder of Einstein's alma mater, the ETH, were able to secure three grants from Switzerland (the Swiss money eventually amounted to a million Swiss francs). Since then, various other grants replaced or supplemented the original grants.

The Project Gets Under Way

While the dispute surrounding the editorship remained unresolved, Stachel was not able to make much editorial progress. In early 1978, he hired Alice Calaprice to organize and carry out the data input and processing for the indexes. Because the project was on a tight budget and computer time on the university's mainframe had become expensive, Calaprice arranged to do most of the computer work during off-hours at no charge at Princeton University's cyclotron laboratory, where the postdoctoral physicist Richard Kouzes trained her in the use of the early computer systems. Two years later, the three indexes were completed with a part-time assistant's help. In the meantime, before the archive was sent to Jerusalem and his own office at the Institute for Advanced Study was closed down, Stachel had also been carefully preparing a conformed duplicate archive to be used in the editorial office to avoid damage to the originals. These copies were used in the preparation of the indexes as well.

The Boston Offices

After 1981, the Institute for Advanced Study no longer offered to house the Einstein editorial office, so Princeton University Press made room for the project in its historic Scribner Building on William Street. Stachel's small staff consisted of editors Robert Schulmann, a historian, and David Cassidy, a historian of physics. After spending almost two years in cramped temporary quarters at the Press in the early 1980s while the future of the project was in limbo, Stachel wanted to return to Boston University, from which he had been on leave for seven years. Neither the Institute for Advanced Study nor Princeton University had been able to offer him a tenured position, but one that would run concurrently only while he remained editor. Arrangements were thus made with Boston University to house the project's new editorial offices on its campus beginning in 1984, and Stachel hired a staff of contributing editors and assistants, retaining Schulmann and Cassidy as associate editors for volume 1. The staff was now in a position to complete the first volume of the papers, published by PUP in 1987.

The translation project became the responsibility of PUP, until 2000 under the administration of Calaprice, who had become an editor in PUP's publishing offices. The first translator was Anna Beck, with Peter Havas as the consultant for volumes 1–2 and Don Howard as consultant for volumes 3–5; then Alfred Engel, with Engelbert Schucking as consultant for volumes 6–7; followed by Ann M. Hentschel, with Klaus Hentschel as consultant for volumes 8–14. The NSF provided seed money and then a regular grant through its History of Science program (later called Science, Technology, and Society), with Calaprice as the principal investigator.

In the interim, Schulmann tracked down important documents that had been in Einstein-family or correspondents' hands for several years. (See Family, "Lieserl' Einstein and the Search to Find Her," for more detail on the discovery of the documents.) The most compelling find was what came to be known as the Einstein-Besso manuscript and dozens of love letters between Einstein and Mileva Marić. The manuscript provided new insight into the early stages of Einstein's struggle with general relativity, while the tender and playful correspondence revealed not only the couple's passion for an independent study of physics (some of their readings can be found in [Part II](#), under Influential Scientific Forebears and Contemporaries), and their shared nonconformist, intellectual life, but also their early intimate relationship. The most startling revelation in the letters was the birth of a daughter, "Lieserl," in early 1902, before their marriage. Other revelations, such as an infamous list of demands made of Mileva later in their marriage, showed that Einstein was not always the benign figure the world thought it had come to know (see Family, *below*). His scientific and humanitarian contributions, however, remained unchallenged.

AN EDITORIAL DIGRESSION

Dukas had taken some liberties with the archive, which led to complications within the project several years later. Ever mindful of Einstein's privacy, she had removed from her office files—or never filed—some of his early correspondence. During his early days in the archive, Stachel had come across some fifty letters from Einstein to his second wife, Elsa, dating from the time they started corresponding in 1912 and having romantic rendezvous. During much of the time covered by the letters, Einstein was still married to Mileva Marić. Before the archive was transferred, Stachel had managed to copy the letters up to the year 1916, not getting to the remaining stack, which ended in 1925. Stachel no doubt believed that while Dukas was still in charge of the archive, these documents, which according to Bailey were in Dukas's "personal collection," might not make it into the public archive in time to be published in the *Collected Papers*.

This hunch turned out to be correct. The staff decided to include the copied letters in their chronological order in volumes 5 and 8. The Hebrew University of Jerusalem, now the copyright owner of the letters, agreed to allow their inclusion since the existence of the cache was by then already known. Six items in the correspondence that Stachel had copied appeared in the published volumes, but the originals are not in the Jerusalem archives. They may have been destroyed, or were simply lost.

Stachel and Schulmann were eager to publish the full correspondence to preserve the integrity of the historical record. To realize their goal, they needed the remaining, uncopied letters from 1916 to 1925 that had not become part of the duplicate archive

and were now only in the archive in Jerusalem. The HUJI, however, declined to give permission to publish the remaining stack, having signed an agreement with Margot Einstein—who had made two bequests of family correspondence in 1982 and 1984—that the letters remain “sealed” until twenty years after her death, which occurred in 1986. Defying this constraint, Schulmann went to Jerusalem in 1996 and copied the remaining letters without the knowledge of the HUJI archives’ personnel or anyone at PUP.

STACHEL RESIGNS, SCHULMANN TAKES CHARGE

In 1988, wishing to resume his faculty position at Boston University full time, Stachel, who was known to be a first-rate scholar but proved to be less interested in administrative obligations, resigned from the project. Disputes with the staff and publisher contributed to his decision to leave. He had completed volumes 1 and 2 with Cassidy and Schulmann as associate editors. Jürgen Renn, a physicist and historian of physics, was added as associate editor for volume 2 and later became editor; Don Howard, a philosopher of science, was assistant editor, and A. J. Kox became contributing editor and, later, editor. After Stachel’s resignation, the EPP offices nevertheless remained in place at Boston University. PUP and the board of trustees appointed Martin J. Klein of Yale University as the senior editor under a five-year contract, and Schulmann and Renn stayed on as editors. In 1993, Schulmann became the senior editor and director of the project. Michel Janssen, a historian of physics, became an editor on volumes 7 and 8.

In 1999, after PUP and HUJI became aware of Schulmann’s activities in Jerusalem, Walter Lippincott, director of the Press since Bailey’s retirement in 1986, and the PUP board of trustees asked Schulmann to resign. In order to maintain continuity and ease the transition after a new director was chosen, he stayed on as contributing editor for volumes 7 and 9.

The Move to Caltech

The task of finding a qualified general editor was no easier at the turn of the millennium than it had been in the 1970s. Diana Kormos Barkan, at the time an associate professor of the history of science at Caltech, was appointed in 2000. She set up new EPP offices in Pasadena, a town that had become familiar to Einstein during his extended visits to Caltech in the early 1930s, which he called “a banishment to paradise.” Barkan, soon to become Buchwald, became the director and general editor of the project, including the translation volumes. Ze’ev Rosenkranz, the former curator of the Einstein Archives at the HUJI and a historian who was already on the EPP editing staff, was appointed assistant director in 2013.

A major and long-awaited accomplishment of the EPP and Princeton University Press was to make the *Collected Papers* available to researchers online on the website <http://einsteinpapers.press.princeton.edu>. The online edition became a significant goal of Buchwald’s after she became director, and it gained momentum with the support of PUP director Peter Dougherty. Both worked toward implementing an open-access, free-of-charge platform. Kenneth Reed at PUP, with the input of the EPP staff, especially Tilman Sauer and Rudy Hirschmann, managed, worked out the technical details, and launched the site with the assistance of other PUP technical staff in December 2014.

Sources: Herbert S. Bailey, “Einstein’s Collected Papers: Planning and Development,” in *Scholarly Publishing*, July 1989, pp. 203–217; Bailey, “Publisher’s Foreword,” *CPAE*, Vol. 1, pp. xi–xiv; Highfield and Carter, *Private Lives of Albert Einstein*, pp. 273–283; Stachel, *Einstein from B to Z*, and personal communications; Stachel, “A Guide to the Duplicate Einstein Archive and Control Index,” 50-page typescript in the Einstein Archives; Alice Calaprice, “Computer Indexing of the Duplicate Einstein Archive,” 23-page typescript in the Einstein Archives; Richard Kouzes, “Technical Description of the Computer Indexing Programs for the Duplicate Einstein Archive,” 5-page typescript in the Einstein Archives; Schulmann’s recollections.

CPAE Volumes and Editors

The volumes published through 2015 are as follows:

- Volume 1 (1987): *The Early Years, 1879–1902*. Edited by John Stachel, with Robert Schulmann and David Cassidy as associate editors
- Volume 2 (1989): *The Swiss Years: Writings, 1900–1909*. Edited by John Stachel, with Robert Schulmann, David Cassidy, and Jürgen Renn as associate editors
- Volume 3 (1993): *The Swiss Years: Writings, 1909–1911*. Edited by Martin J. Klein, A. J. Kox, Jürgen Renn, and Robert Schulmann, and contributing editors
- Volume 4 (1995): *The Swiss Years: Writings, 1912–1914*. Edited by Martin J. Klein, A. J. Kox, Jürgen Renn, and Robert Schulmann, and contributing editors
- Volume 5 (1993): *The Swiss Years: Correspondence, 1902–1914*. Edited by Martin J. Klein, A. J. Kox, and Robert Schulmann, and contributing editors. For his work in this volume, Schulmann won the 1994 prize for best publication in the history of science, an award presented by Asea Brown Boveri (ABB).
- Volume 6 (1996): *The Berlin Years: Writings, 1914–1917*. Edited by A. J. Kox, Martin J. Klein, and Robert Schulmann, and contributing editors
- Volume 7 (2002): *The Berlin Years: Writings, 1918–1921*. Edited by Michel Janssen, Robert Schulmann, József Illy, Christoph Lehner, and Diana Kormos Buchwald, and associate editors
- Volume 8 (1998): *The Berlin Years: Correspondence, 1914–1918*. Two volumes. Edited by Robert Schulmann, A. J. Kox, Michel Janssen, and József Illy, and contributing editors
- Volume 9 (2004): *The Berlin Years: Correspondence, January 1919–April 1920*. Edited by Diana Kormos Buchwald, Robert Schulmann, József Illy, Daniel Kennefick, and Tilman Sauer, and associate editors
- Volume 10 (2006): *The Berlin Years: Correspondence, May–December 1920*. Edited by Diana Kormos Buchwald, Tilman Sauer, Ze’ev Rosenkranz, József Illy, and Virginia Iris Holmes, and associate editors
- Volume 11 (2009): *Cumulative Index, Bibliography, List of Correspondence, Chronology, and Errata to Volumes 1–10*. Compiled by A. J. Kox et al. This volume won the 2009 Wheatley Medal award for indexing excellence, presented by the Society of Indexers.
- Volume 12 (2009): *The Berlin Years: Correspondence, January–December 1921*. Edited by Diana Kormos Buchwald, Ze’ev Rosenkranz, Tilman Sauer, József Illy, and Virginia Iris Holmes, and associate editors
- Volume 13 (2012): *The Berlin Years: Writings and Correspondence, January 1922–March 1923*. Edited by Diana Kormos Buchwald, József Illy, Ze’ev Rosenkranz, and Tilman Sauer, and associate editors
- Volume 14 (2015): *The Berlin Years: Writings and Correspondence, April 1923–May 1925*. Edited by Diana Kormos Buchwald, József Illy, Ze’ev Rosenkranz, Tilman Sauer, and Osik Moses, and associate editors

Fame

The Media

Einstein achieved worldwide fame in late 1919, when the scientific breakthrough of his general theory of relativity, as tested by British astronomers in South America and Africa during a total eclipse of the Sun, was trumpeted to all corners of the globe by a mass media that became increasingly influential and pervasive after the world war. A photogenic Einstein was catapulted onto the world stage in the guise of a revolutionary genius, a role for which he proved to be well cast. Blessed with a theatrical bent, he slyly and humorously toyed with journalists, all the while feigning naiveté. During the early 1920s, journalists and would-be science experts vied to satisfy public curiosity about Einstein’s ideas, opinions, and personal habits. “Relativity” became a buzzword in popular culture. Fame, however, came at a stiff price. Surrounded by social and economic unrest in Berlin, Einstein was caught between two worlds, one struggling to be born, another unwilling to yield its privilege. Emerging from the temple of science to which he had dedicated his first forty years, his internationalist stance became a rallying point in the early Weimar Republic for liberal supporters and a focus of hatred for its foes. A decade later, his public image acquired another layer when he took on the persona of selfless

humanitarian— “a Jewish saint,” as he mockingly called himself.

Despite ample evidence of outward success, Einstein still had deep misgivings about his new public roles. Elsa Einstein confided to Harry Count Kessler that her husband sometimes “felt like a cheat, a confidence trickster who was failing to give [his admirers] whatever they hoped for” (Harry Kessler, *Berlin in Lights*, p. 155). This remark from 1922 reflects the burden of fame that was already weighing heavily on Einstein’s personal life. By turns reluctant and bemused, he accepted his status as a living legend and spent the final thirty-five years of his life in and out of the public eye. During much of this time, he and his admirers helped shape iconic images of the great physicist. More recent accounts, however (such as Misner, “Why Einstein Became Famous”), have analyzed how Einstein’s celebrity and notoriety were heavily conditioned by scientific, cultural, and political expectations.

Art and Commercialism

Since 1919, Einstein has been memorialized and honored in various—and often crude—ways. His name has been appropriated for scholarships, endowed university chairs, grants, schools, buildings, and memorial sculptures. Einstein impersonators rival Elvis impersonators in number. His face appears in countless works of art, on postage stamps and coins, and in commercial offerings such as T-shirts, posters, coffee mugs, bobble-heads, and the Baby Einstein multimedia and toy line of products. According to Dorothy Pomerantz, who runs the annual Dead Celebrity list of earnings for *Forbes* magazine (limited to thirteen people), in 2013 Einstein’s image earned Hebrew University \$10 million. HUJI has reported that, once it subtracts the legal expenses it expends to protect Einstein’s image, it receives only a small fraction of the revenues. (See <http://www.forbes.com/pictures/mfl45ehfld/albert-einstein-5/>; Ha’aretz.com, October 24, 2012.)

Other ventures, though they may not be pleasing to everyone’s eye, attempt to produce art and memorialization in various forms, and here we present a few examples.

The first large-scale structure named for Einstein was the Einstein Turm (Tower) outside of Berlin in Potsdam (fig. 12). Designed by the visionary expressionist architect Erich Mendelsohn, with the young Richard Neutra on his team, this solar observatory was completed in 1924 in an unusual Art Deco style. When Mendelsohn escorted Einstein on a tour of the tower, Einstein is said to have commented simply that the amorphous structure is “organic.” Constructed of reinforced concrete, it is designed to both represent and facilitate the study of relativity theory. The tower was severely damaged during the Second World War and did not reopen until 1999, after considerable restoration work had been completed. (See also Hentschel, *The Einstein Tower*.)



(a)



(b)

FIGURE 12. (a) The Einstein Tower in Potsdam, near Berlin. (Astrophysikalisches Institut Potsdam/Wikimedia Commons.) (b) Cartoon of the Einstein Tower by Josef Plank, depicting Einstein being swept off the tower and out of Germany after the Nazi seizure of power. The tower, a solar observatory designed to test general relativity, was a symbol of modernism in both the arts and the sciences, and a target of anti-Semitic and reactionary attacks. Einstein referred to it as “organic.” (Library of Congress LC-USZ62-94410)



FIGURE 13. “The nose as thought reservoir.” Cartoon by Ippei Okamoto, a Japanese social and political satirist, drawn during Einstein’s visit to Japan in 1922. (From Japanese newspaper *Asahi Shimbun*, 1922)

Many artists, photographers, and sculptors—not to mention cartoonists—have strived to capture Einstein’s photogenic image. Among the better-known artists are Josef Scharl, Ben Shahn, Georges Schreiber, and Hermann Struck. Portrait photographers Philip Halsmann (also spelled Halsman), Herman Landshoff, Lotte Jacobi, and Yousef Karsh have been particularly successful in their artistic efforts by producing enduring and much-used images in black and white, which can still be purchased from their heirs or agencies licensed to sell them. Halsmann’s 1946 photograph is the most famous of all. It was reproduced on an 8-cent U.S. postage stamp in 1966 and in myriad images that artists overlay with their own interpretations of Einstein. (Halsmann himself was a beneficiary of his most famous subject’s humanitarian impulse. During an intense wave of anti-Semitism in Austria in the late 1920s, he was wrongfully accused and convicted of murdering his father while on an excursion in Austria’s Tyrolean Alps, an incident that became known as “the Austrian Dreyfus Affair.” Einstein was later instrumental in helping to bring Halsmann to the United States and having his criminal record expunged by the Austrian government. See <http://www.reformjudaismmag.net/1100dw.html> for the full story.)

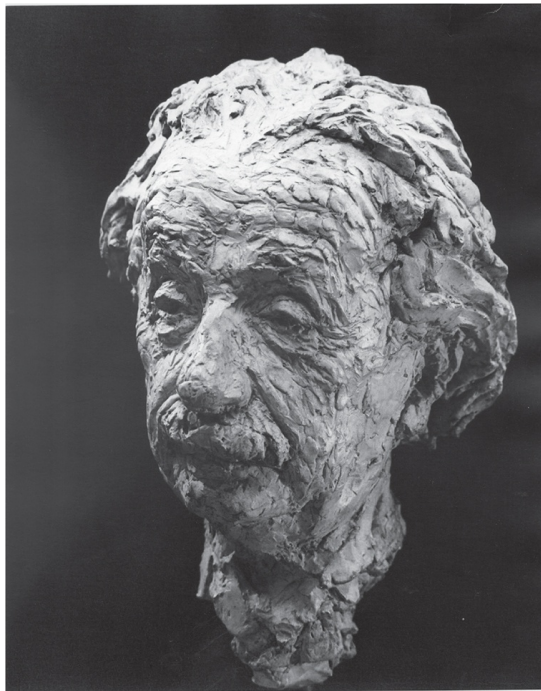
In December 1922, during Einstein’s visit to Japan, political and social cartoonist Ippei Okamoto sketched a particularly memorable cartoon of Einstein with an enlarged nose, writing under it: “The nose as a reservoir for thoughts” (fig. 13). Okamoto observed that Einstein “has a quiet way of walking, as if he is afraid of alarming the truth and frightening it away” (Einstein Archives 160-230; see also *American Journal of Physics* 49 [1981]: 931).

Among sculptures, the most notable is the enormous Einstein Memorial statue in front of the National Academy of Sciences in Washington, DC, sculpted in bronze by Robert Berks, based on a plaster of Einstein’s head sculpted twenty-six years earlier (fig. 14a). Unveiled in 1979 during the Einstein centennial celebrations, it depicts Einstein sitting on a curved granite, three-step bench, holding a manuscript. The statue is large enough for children to clamber (fig. 14b). Berks also produced a bronze roughcast bust on a granite pedestal for a much smaller, six-foot memorial statue placed in front of Princeton’s Borough Hall. It was unveiled in 2005 after years of opposition from members of the community who believed Einstein’s wish not to be memorialized should be honored, quoting his own words that he wanted no one “to come to worship at my bones.” Close to the pond at Princeton’s Institute for Advanced Study, in a serene sylvan setting, visitors can find an imposing and bold black steel rhombus by sculptor Tony Smith titled “New Piece,” which the Institute unveiled in 1981 to memorialize its most famous faculty member. A fine bronze bust created by Russian sculptor Sergei Konenkov and commissioned by Princeton University is also located at the Institute, in the Mathematics-Natural Sciences Library in Fuld Hall. Konenkov, sometimes called “the Rodin of Russia,” worked in the United States from approximately 1935 to 1945, when Stalin recalled him and his wife, Margarita, to the Soviet Union. (See also Romantic Interests, “Margarita Konenkova,” below.) Ulm, the city of Einstein’s birth, where he lived for the first fifteen months of his life, honors him with at least four memorial statues, including a fountain that features Einstein sticking out his tongue at the world, as in the popular photo that has been so widely circulated. Aarau, Switzerland, where Einstein lived briefly before his college days, has a copper memorial plaque by T. Duttenhoefer. Pasadena City College has a small plaque in its astronomy building and observatory that commemorates Einstein’s visit there in February 1931. No doubt, many other such plaques have been installed all over the world.

In 1933, Einstein sat for Sir Jacob Epstein, a pioneer in modernist sculpture, and he cast six bronzes from that sitting in Cromer, Norfolk, England. The portrait sculptures are at the Fitzwilliam Museum in Cambridge, England; the Hebrew University in Jerusalem, in the Mathematics and Computer Science Library; the Huddersfield Art Gallery in West Yorkshire, England; the Institute for Advanced Study, Princeton, in the Common Room of Fuld Hall; the Science Museum of London; and the Tate Gallery in London.

Visitors to New York City can view an unusual sculpture of Einstein at the Riverside Church overlooking the Hudson River, where Harlem and the Upper West Side meet. In the tympanum over the west portal of the church, built in 1929, Einstein is immortalized in stone, wedged in among other great scholars and scientists, including Archimedes, Darwin, Euclid, Galileo, Kepler, Pasteur, and

Pythagoras (fig. 15).



(a)



(b)

FIGURE 14. (a) The original plaster cast of the head of Einstein sculpted by Robert Berks in Einstein's study on Mercer Street in 1953. It became the inspiration for the head of the Einstein monument installed in front of the National Academy of Sciences in Washington, DC, in 1979. (© 2003 Robert Berks Studios, Inc.) (b) Children climbing on the Washington, DC, monument. (Courtesy Jason MacLurg, MD)



FIGURE 15. Einstein permanently embedded in the tympanum of Riverside Church in New York City. (Photo © Alice Calaprice)

A lesser-known masterpiece is a piece of natural, organic art: the Large-cupped Narcissus “Professor Einstein,” a flower that flaunts a shock of white petals around its center orange cup and has been available since the 1940s, now also through the Internet.

Finally, to please both children and adults, the Legoland theme parks in California, Florida, and Malaysia have erected gigantic busts of Albert Einstein that greet visitors

in the Imagination Zone (fig. 16). Builders worked for several months using hundreds of thousands of Legos to complete the images, which are around 15 feet high and 20 feet wide, in Orlando, Florida (opened in 2011), in Carlsbad, California (1999), and in Johor Bahru, Malaysia (2012).



FIGURE 16. Einstein's head, constructed of hundreds of thousands of pieces, at Legoland, Carlsbad, California, with Lego enthusiasts, 2014. (Photo © Denise Calaprice-Whitty)

Family

Family Relationships

(See *also* individual family members, *below*.)

Einstein's family relationships were complex because of his two marriages and one divorce, creating two distinct families, which later in life even straddled two

continents (see [figs. 17](#) and [18](#)). Wars, fame, immigration, a daughter born out of wedlock, a mentally ill son, and his roving eye often complicated matters.

Einstein's ties with his birth family were less knotty, however. He had a lifelong close relationship with his sister, Maria (Maja), who was two years his junior and shared much of his indifference to convention. The strong bond with his mother, Pauline, drew on his admiration for her discipline and perseverance, though it in no way lessened his ridicule of her ambition for him. A degree of resentment and emotional distance lingered toward his father, Hermann, whom he considered a weakling for yielding on business matters to his own brother.

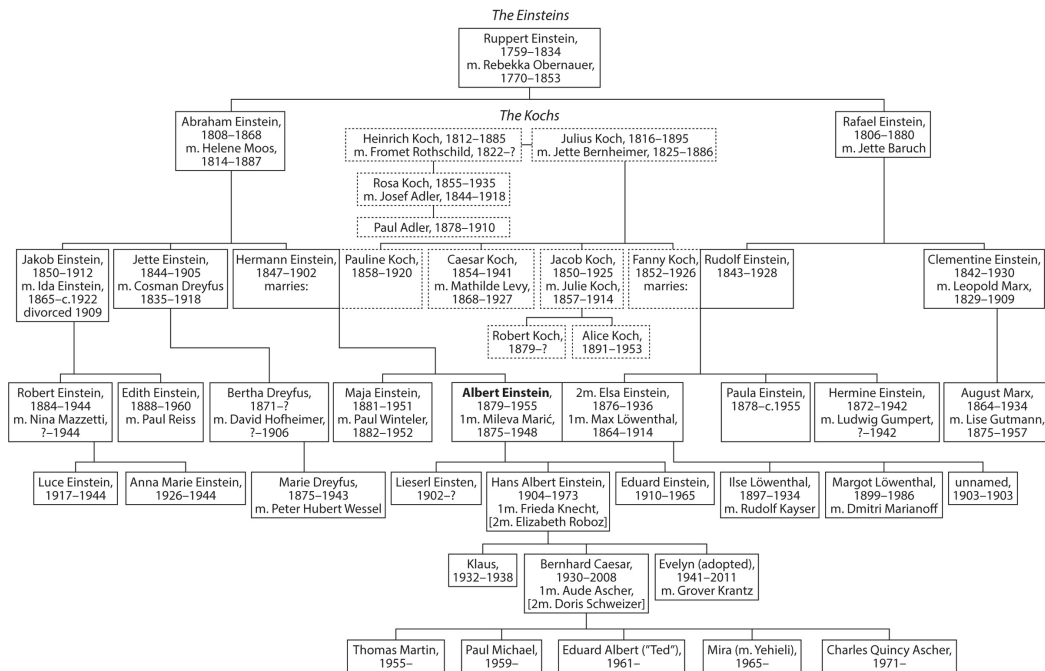


FIGURE 17. Einstein family tree.



FIGURE 18. Earliest known photo of Albert Einstein, ca. 1882. (Courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel)

At the ETH in Zurich, he began a romantic relationship with a Serbian classmate, Mileva Marić, whom he married soon after graduation in 1903. A daughter and two

sons were born to the couple; the daughter, referred to as “Lieserl” in their correspondence, arrived before their marriage. Due to the mystery surrounding the so-called Lieserl’s birth and life, it is unclear what Einstein felt for her, though his initial enthusiasm is evident from his correspondence with Mileva (see *CPAE*, Vol. 1, and the *Einstein-Marić Love Letters*). After a few mentions in the letters, however, Lieserl vanished and her whereabouts were never discovered.

Einstein’s relationship with his two sons, Hans Albert and Eduard, was complicated by what became a troubled marriage to Mileva that ended in separation in 1914 and divorce five years later. The separation was all the more painful for both father and sons as it was reinforced by geographic distance: mother and sons lived in Zurich, while Einstein held an academic position in Berlin. Hans Albert, who at the time of the separation at the beginning of the war was ten years old, resented what he considered his father’s abandonment of the family. If he was aware of his father’s ultimatum to his mother just before the family’s departure from Berlin, the son’s resentment could only have deepened (see below, “Family No. 1—Mileva Einstein-Marić”).

Both boys were further alienated from their father during the war years when he would promise to visit and then renege, often due to work-related responsibilities and difficulties with wartime travel. For his part, Einstein complained bitterly that Hans Albert often would not respond to the letters in which he had sought to explain his absence. Two efforts to divorce Mileva during the war years further damaged Einstein’s relationship with the boys. On his father’s divorce from Mileva in February 1919 and marriage to Elsa later in the year, Hans Albert vigorously defended his mother. Eduard, a sickly child, nine at the time of the divorce, was clearly affected by the parents’ estrangement but was less bitter toward Einstein than was his older brother.

Yet Einstein’s concern for his boys’ welfare was also evident. Well before receiving the Nobel award, Einstein had pledged the substantial prize money toward the support of Mileva and their sons. In 1922, as promised, he gave the yield from the award outright to Mileva; the principal was intended for the family’s care, but Einstein retained control over its investment. The money was used to purchase an apartment house and other properties in Zurich that for a time provided a comfortable income. Hans Albert’s technical facility was also a source of pride to his father during the summers in the early 1920s when Hans Albert was a welcome guest in the engineering laboratory of Einstein’s friend, the industrialist Hermann Anschütz-Kaempfe (see *Collaborators*, and *Patents and Inventions*, both in [Part II](#)).

When Einstein drew up a last will and testament in July 1923, and again in his wills of 1925 and 1950, he favored the family of his new wife, Elsa, over that of Mileva’s. This revelation resulted in new tensions between Hans Albert and his father and generated animosity between Family No. 1 (Mileva’s) and Family No. 2 (Elsa’s). After Einstein grudgingly accepted Hans Albert’s marriage to Frieda Knecht (1927), a union he had vehemently opposed initially, his relationship with his older son improved, and in later years he showed genuine respect for Hans Albert’s accomplishments. Einstein engaged in a lifelong struggle to come to terms with his younger son Eduard’s physical and mental illnesses, although, of the two boys, he thought Eduard might be the more gifted.

The contrast between Einstein’s conflicts with his sons and his uncomplicated paternal affection for Ilse and Margot, Elsa’s children from an earlier marriage who became part of his home life and household, is noteworthy. The notion that he had legally adopted Elsa’s children, however, has no basis. At the time Einstein was about to marry Elsa, her daughters were already adults at ages twenty and twenty-two but living at home. Einstein biographers have stated that Einstein adopted the “girls,” but we have not found evidence of legal adoptions, nor does any archival correspondence refer to such a process. After Elsa was divorced from her first husband, she had slowly reverted to using her maiden name, which was also “Einstein,” and the girls took that name as well—perhaps after their father’s death in 1914—a custom that was not unusual in Germany. An indication of this likelihood is Ilse’s early use of “Einstein” in her inscribed schoolbooks. Margot legally changed her surname to Einstein around the age of twenty, as shown by a change in her birth certificate, but without any mention of an adoption by Albert Einstein. Furthermore, in his first will of 1923, Einstein does not refer to the young women as his stepdaughters or by name, but only as Elsa’s daughters. Therefore, it seems that Ilse’s and Margot’s use of the Einstein

name came through the adoption of their mother's maiden name. Nevertheless, he clearly had great affection for his stepdaughters and considered them his family, perhaps even more so than his own sons, and in time Ilse and Margot referred to him as their father.

Einstein's relationship with Elsa had the character of a practical arrangement. Elsa and Einstein were first and second cousins (see [fig. 17](#)), and the two had played together as children. When he suffered severe medical setbacks in summer 1917 and winter 1917–1918, Elsa nursed him back to health and continued to be his helpmate until her death in 1936 at the age of sixty. She basked in her husband's fame but found it difficult to adjust to his wandering eye and numerous extramarital affairs.

Hitler's seizure of power in Germany drove Albert Einstein from Europe in 1933. He paid what turned out to be a final visit to his ailing younger son, Eduard, in a psychiatric sanatorium near Zurich, after which he never saw him again. Once Einstein was established in the United States, he urged his older son, Hans Albert, and his family to immigrate, and he was able to secure Hans Albert a position with the U.S. Department of Agriculture in South Carolina. Einstein stayed on civil terms with his daughter-in-law, but there was little warmth in the relationship. At the time Hans Albert and Frieda immigrated in 1938, they had two sons, Bernhard Caesar and Klaus Martin (who died in 1939); three years later, they adopted a daughter, Evelyn.

Elsa and Helen Dukas had already accompanied Einstein to Princeton when he began an appointment at the Institute for Advanced Study in Princeton in 1933. Margot came the next year, and Einstein's sister, Maja, joined them in 1939, leaving her husband behind due to medical reasons that prevented him from immigrating. Einstein showed great tenderness toward Maja in her later years as her health declined. In the four years remaining to him after her death in 1951, Einstein showed similar devotion to the other women in his household, whom he patriarchally but affectionately called his *Hühnerhof* (chicken yard).

Grandparents and Parents

Einstein's forebears came from Württemberg in the southwest of Germany. His paternal grandfather, Abraham, was from the village of Buchau am Federsee; his maternal grandfather, Julius Dörzbacher (surname later changed to Koch), was first a baker and then a prosperous grain merchant in Cannstatt near Stuttgart, a trade that had been open to Jews since the Middle Ages. Little is known of Abraham's profession and even less about his wife, Helene née Moos. Einstein's sister later related that the maternal grandmother, Jette née Bernheimer, was "the soul" of her family. (See Maja Winteler-Einstein's memoir of her brother, "Albert Einstein. Beitrag für sein Lebensbild" [Biographical Sketch], February 15, 1924, *CPAE*, Vol. 1, p. xlix.)



FIGURE 19. (a) Hermann and (b) Pauline Einstein. (Wikimedia Commons)

Hermann, Einstein's father (born in 1847 in Buchau, Germany), and his mother, Pauline (born in 1858), were eager—as were most German Jews born in the mid-nineteenth century—to obtain for themselves the civil liberties and economic opportunities only recently and grudgingly conceded by Jewish emancipation (fig. 19a, b). Hermann became a merchant, first in the feather-bed business and later in a series of electrical-business ventures with his brother Jakob, while Pauline was a mother and homemaker. Once old barriers began to crumble, many Jews like the Einsteins sought to assimilate by relegating restrictive categories of religion, ancestry, and tradition to the margins—though they did offer their son private instruction in the Jewish religion at the home of a relative.

Hermann and Pauline Einstein spoke little of religious matters or rules. Their relative indifference may account in part for their young son's rebellious embrace, with almost fanatical zeal, of dietary laws and other Jewish traditions. This phase came to an abrupt end at the age of twelve. Ironically, it was the influence of a poor Jewish student, Max Talmey, to whom the family offered free meals at their home as an act of charity, which turned the young Einstein's interest from religion to the natural sciences.

Hermann Einstein died of heart failure in 1902 at the age of fifty-five, in Milan, Italy. Pauline died of abdominal cancer in 1920 at age sixty-two in Berlin, while living with her son and Elsa.

Sister: Maria (Maja) Winteler-Einstein—Husband, Paul Winteler

Einstein's sister, Maja (fig. 20), was born in Munich on November 18, 1881, two and a half years after her brother's birth in Ulm. She wrote a memoir of her reminiscences about Albert as a young boy, the early part of which was reprinted in volume 1 of *The Collected Papers of Albert Einstein*. In it, she recalled that before she was born, Albert had been told that he would soon have something to play with. Her birth revealed that she clearly was not a toy, and he lamented, "But where are its wheels?" She also reported that he was a temperamental young child and that she was his only constant playmate.

In 1894, after she moved to Milan, Italy, with her parents, Maja attended the German International School there. She attended a *Lehrerinnenseminar* (teacher's college) in Aarau, Switzerland, from 1899 to 1902, then delved into the study of Romance languages and literature in Berlin beginning in 1905. She moved to Bern in April 1907 and was accepted as a doctoral student at the university, wrote her PhD dissertation, and passed the oral exam on December 21, 1908. In 1909, she formally received a doctorate on a topic in French literature, "Contribution to the Tradition of the Chevalier au Cygne and the Enfances Godefroi." She never used her degree in a professional way.



FIGURE 20. Einstein's younger sister, Maja, at age sixteen, ca. 1897. (Gift of Evelyn Einstein)

In 1910, she married Paul Winteler, one of seven children of Jost and Pauline Winteler, with whom Einstein lived when he was attending the cantonal secondary school in Aarau (*see* Friends, "Winteler Family"). The young couple moved to Lucerne in 1911, and after eleven years took up residence near Florence, where they lived until 1939. They had no children. Following the introduction of Mussolini's anti-Semitic laws, Maja moved to Princeton to live with her brother. Her husband moved

to Geneva and stayed in Europe, having been denied immigration to the United States for medical reasons. In 1946, after suffering from heart disease, Maja had a serious stroke and remained bedridden until her death. Einstein was devoted to his sister during her years of incapacity, reading to her regularly at her bedside. She died in June 1951. Her husband, Paul, died in Geneva a year later.

*Sources: CPAE, Vols. 1, 5; Rogger, *Einsteins Schwester*.*

Family No. 1 (Consisting of Einstein, Mileva, and Their Offspring)

MILEVA EINSTEIN-MARIĆ—FIRST WIFE

Einstein's first wife, Mileva Marić ([fig. 21](#)), was born in Titel, Hungary (now located in Serbia), on December 19, 1875. She was one of two daughters (younger sister, Zora or Zorka) and one son (Miloš Jr.) of a Serbian, well-to-do midlevel civil servant named Miloš Marić and his wife, Marija. Mileva began school in 1882 in the town of Ruma, then attended several secondary schools, including one for boys in Zagreb, Croatia, before studying medicine for a semester at the University of Zurich and then physics at the ETH, like Einstein. Because of the restraints on girls to attend a university in the Austro-Hungarian Empire, especially to study the natural sciences, Mileva moved to Switzerland. She took off a semester in 1897–1898 to audit courses in mathematics and physics in Heidelberg, then returned to the ETH. The romantic relationship with Einstein may have begun in late 1898, when he was nineteen and she was twenty-three and both were students. When the two sweethearts were apart, they exchanged playful and affectionate letters and notes, exulting in their relationship and sharing each other's progress with work and school. Einstein's parents, especially his mother, strongly objected to the relationship from the start, and more so when Einstein announced his plans to marry Mileva. Bearing the usual cultural animus of her generation of Germans against East Europeans, Pauline Einstein thought her son's future would be in jeopardy with a woman she considered to be an unsuitable wife. Hermann, on the other hand, would give his blessings for the relationship, if not enthusiastically, on his deathbed in 1902.



FIGURE 21. Mileva Marić, Einstein's first wife. (Wikimedia Commons)

In 1900 and 1901, Mileva made two unsuccessful attempts to receive a teaching diploma from the ETH. In 1901, she also became pregnant, and in January 1902 she gave birth to a baby girl, whom she and Einstein called “Lieserl,” somewhere in Serbia (see “‘Lieserl’ Einstein and the Search to Find Her,” *below*). A year later, on January 6, 1903, the couple married in Bern in a civil ceremony.

Einstein and Mileva continued to live in Bern after their marriage, from 1903 until 1909. Though she never received her diploma from the ETH nor a doctorate from the University of Zurich as planned, Mileva was still interested in Einstein's ongoing work and probably discussed it with him, checked calculations, and did bibliographic searches. On the other hand, as Maurice Solovine, a member of the Olympia Academy (1902–1903; see [Part III](#), Organizational Ties), related: “Mileva, intelligent and reserved, listened attentively but never intervened in our discussions” (*Letters to Solovine, 1906–1955*, p. 13). After the birth of their first son, Hans Albert ([fig. 22](#)), in Bern in 1904, Mileva stopped pursuing a career in physics. Scholars dismiss the idea that she was a scientific collaborator in the conventional sense. Others have challenged that view, relying mostly on third- and fourth-hand information gathered decades after the fact. (See also *Myths and Misconceptions*, “Mileva Marić as Alleged Collaborator.”) Einstein became more and more involved in his work while Mileva

concentrated on child care and housekeeping duties. Their resolution to remain as two outsiders against the world faded.

In 1909, the family moved to Zurich, where a second son, Eduard ([fig. 22](#)), was born in 1910. In 1913, Mileva and the boys went to visit her parents. During that stay, the boys were baptized in the Serbian Orthodox church.

After a year in Prague and then the move to Berlin in April 1914, it became clear that the Einsteins' marriage was in trouble. In 1912, Einstein had begun an affair with his cousin Elsa Löwenthal, who lived in Berlin, and his neglect of Mileva deepened. Nevertheless, divorce was not an immediate option. In Berlin, he briefly considered continuing to live with her and the boys (while also courting Elsa) under a set of harsh conditions he presented to her in the form of an ultimatum:



FIGURE 22. Einstein's sons Eduard (left) and Hans Albert, ca. 1918 in Switzerland.
(Courtesy of the Leo Baeck Institute)

(A) You will see to it that (1) my clothes and laundry are kept in good order;
(2) I will be served three meals regularly *in my room*; (3) my bedroom and

study are kept tidy, and especially that my desk is left *for my use only*. (B) You will cease all personal contact with me insofar as it is not absolutely necessary for social reasons. In particular, you will forgo (1) that I sit at home with you; (2) that I go out or travel with you. (C) You will obey the following points in your relations with me: (1) you will not expect any tenderness from me, nor reproach me in any way; (2) you will stop talking to me about something if I request it; (3) you will leave my bedroom or study without any backtalk if I request it. (D) You will undertake not to belittle me in the eyes of my children, either through words or through actions. (“Memorandum,” ca. July 18, 1914, *CPAE*, Vol. 8, Doc. 22; Einstein Archives 75-980)

At first, Mileva accepted the conditions, but Einstein seems to have withdrawn the offer, and she left Berlin with the children on the eve of the First World War (July 31, 1914). The relationship soured further following their separation, and in 1919, the couple divorced. In 1922, Einstein gave Mileva the yield from his Nobel Prize money, in accordance with their divorce settlement, controlling but not keeping the principal. (By 1919 he had already been nominated for the prize several times, so it was assumed he would eventually receive the honor.) Mileva bought income property for herself and the boys—including a five-unit apartment house in Zurich—and Einstein also continued to pay the family’s considerable medical bills. To supplement the family’s income, Mileva gave piano lessons.

Mileva suffered from bouts of depression, though her early correspondence also reveals a playful side. Her younger sister, Zorka, was afflicted with schizophrenia and died in middle age. Mileva had been sickly as a child as well; both she and Zorka were born with a luxated hip that caused a lifelong limp. When Einstein met Elsa, he confided to her that living with Mileva was not easy—that she was a cross he had to bear, presumably for the sake of the young children. Yet the love letters written between Einstein and Mileva at the time of their budding romance tell a different story.

After the couple’s separation, Mileva suffered a nervous breakdown, diagnosed as cerebral tuberculosis, in spring 1916 and spent six months in recovery in a sanatorium while a housekeeper and friends cared for the boys. The following year she complained of heart problems, and at other times she suffered from back and spinal pain, headaches, glandular swelling, the flu, a neck and jaw infection, and scrofula, a form of tuberculosis affecting the lymph nodes (see *CPAE*, Vol. 8, index, for her various documented afflictions). Throughout her life as a mother, she also had the burden of being primary caretaker for Eduard, a frail and sensitive boy who was diagnosed with schizophrenia at the age of twenty-two when he was a medical student. Accounts from various contemporaries paint a picture of an embittered woman, though her relationship with Einstein achieved a kind of equilibrium of mutual respect. After having said many unkind things to Mileva in earlier years, Einstein admired the devotion she had always shown their boys and how she raised them (see his letter to her, August 28, 1921, *CPAE*, Vol. 12, Doc. 218; Einstein Archives 75-721).

Mileva died in August 1948 in Zurich, where she is buried in the Nordheim cemetery (see Einstein Archives 72-001 to 72-003, in Serbian).

Sources: *CPAE*, Vols. 1, 5, 8, 12; Popović, *In Albert’s Shadow*.

“LIESERL” EINSTEIN AND THE SEARCH TO FIND HER

Einstein’s first child, a daughter whom he consistently referred to as “Lieserl,” was born out of wedlock a year before he married the child’s mother, Mileva Marić. To this day, the girl’s birth and life remain an enigma. Her birthplace, precise date of birth, and the course of her life are unknown.

In May 1901, Einstein arranged a rendezvous with Mileva at Lake Como in northern Italy and together they traveled from there to Switzerland. Lieserl was conceived on this trip and was born in late January 1902, probably in or somewhere close to Mileva’s hometown of Novi Sad (then in the kingdom of Hungary, today in Serbia). Einstein had hoped for a boy, but wrote of his joy at Lieserl’s birth and inquired longingly about her appearance and health (see letter to Mileva Marić, February 4, 1902, *CPAE*, Vol. 1, Doc. 134; Einstein Archives 76-419). Mileva returned

to Switzerland some time in 1902 without the child. Shortly before Lieserl's first birthday, her parents were married on January 6, 1903, in Bern, where Einstein held a provisional appointment at the Swiss Federal Patent Office. In August 1903, Mileva returned to Novi Sad, where she reported that their daughter had survived an attack of scarlet fever. In response, Einstein asked how Lieserl was registered and urged Mileva to ensure that no difficulties would later befall the child (see letter to Mileva Marić, September 19?, 1903, *CPAE*, Vol. 5, Doc. 13; Einstein Archives 76-360). No evidence of registration has been found. The letter of mid-September is the last known written mention of Lieserl by either Einstein or Mileva. Though there have been numerous hypotheses about her fate, no recorded name or corroborating documentation of Lieserl's life has ever been found.

The story of the discovery of the letters revealing Lieserl's existence is almost as strange as the riddle of her fate. In 1985, associate editor of the *Collected Papers*, Robert Schulmann, heard rumors in Switzerland that correspondence between Einstein and Mileva during their courtship, the so-called Love Letters, long thought lost or destroyed, might still exist. Upon her death in Zurich in 1948, Mileva's literary estate had been passed to her older son, Hans Albert, in Berkeley, California, and after his death in 1973, to his second wife, Elizabeth Roboz-Einstein. *CPAE* editor John Stachel had known since 1979 that the Mileva cache was in the hands of Roboz-Einstein, but the inventory of these documents, their scope and contents, remained a mystery. Few outsiders also knew that Hans Albert and his first wife, Frieda Knecht, had prepared a selection of the letters for publication and submitted a manuscript to a Swiss publishing house, Origo Verlag.

Though Hans Albert and his wife owned the letters in their possession and could legally sell them, they discovered when trying to publish those written by Einstein that publication rights lay with the author's estate and not with them. The executors of the estate, Otto Nathan and Helen Dukas, proposed granting permission only if they might view the originals and decide which letters could be included in the proposed book, a proposition that Hans Albert categorically refused. The galleys of the book of letters languished in a bank vault in Switzerland. The standoff of no permission, on the one hand, and no access, on the other, persisted until the mid-1980s. By this time, the power to grant permission had passed to the ultimate heir of Einstein's literary estate, the Hebrew University of Jerusalem (HUJI).

At Christmas 1985, Schulmann paid a visit to Einstein's granddaughter, Evelyn, in Berkeley, who, almost as an afterthought, showed him a manuscript version of the book that Evelyn's father and mother had written and been unable to publish decades earlier. The manuscript contained transcriptions of letters from the later period of Einstein and Mileva's marriage and divorce, but there were none from their courtship days. Filial piety had dictated that Hans Albert not include transcriptions of the Love Letters, but evidence of their existence fell unexpectedly out of the manuscript's plastic envelope. There were numerous fragmentary citations on slips of papers that referred to a premarital affair and to the love child. Schulmann conjectured that the fragments were cited from material in Mileva's literary estate and that the originals might still be there. Proceeding on this assumption, Stachel approached HUJI, with whom the editors and Princeton University Press had a publication agreement. In 1986, an arrangement to grant access to the entire collection was agreed upon by Stachel, HUJI representative Reuven Yaron, and Hans Albert's heirs.

Stachel and Yaron left immediately for San Francisco, where the originals were held. During a long night of work in a bank vault, they made copies of the entire collection. The conjecture had proven correct. The Love Letters, forty-three from Einstein to Mileva and eleven from her to him, were nestled in Mileva's literary estate of approximately 450 letters. The fact that these early letters by Einstein were written in the old German script created another layer of inaccessibility. The path was now open to honor Hans Albert's wish for publication and for the *Collected Papers* to include the letters in the series.

The paper trail to Lieserl had been blazed, but tracing the path of the real Lieserl has proved more daunting. Almost immediately after copies of the Love Letters were obtained in spring 1986, the editors began a search for Lieserl, including two research trips, to Novi Sad and to nearby Kać, where Mileva's family had a summer house. Schulmann scoured archives and birth registers and conducted interviews with potential informants. Rumors abounded, but this time they yielded no documentary evidence, only the thinnest of conjectures. Other researchers entered the fray as well.

In the end, she remains as elusive a figure as her parents apparently intended.

HANS ALBERT EINSTEIN—WIVES: FRIEDA KNECHT; ELIZABETH ROBOZ

Hans Albert was the Einsteins' first son, born in Bern in 1904 while his father was a clerk at the Swiss Federal Patent Office. From Mileva's extant letters, it is clear that Einstein was very attached to the child and played with him often. After the parents' separation and divorce, however, the relationship became much more strained, as Einstein tended to neglect his sons while he was living in Berlin. Wartime travel difficulties exacerbated the situation. Hans Albert often complained in his letters to his father about various difficulties the family was having. Einstein did manage to make several visits to see his boys, and even stayed with them at Mileva's home in Zurich. Father and sons particularly enjoyed excursions into the Swiss mountains when they were together.

Hans Albert became an independent and intelligent young man who, like his younger brother, did well in school and was musically inclined. He decided on a career in civil engineering and attended the same college as his father, the Swiss Federal Polytechnical School, though by then it was called the ETH (Eidgenössische Technische Hochschule) in Zurich. He completed his studies in hydraulic engineering in 1926 and took a job with a company building hydraulic steel structures in Dortmund, Germany. His relationship with his father remained cool for many years, though there were moments of quiet pride as well: "My Albert has become a capable, solid fellow. [Marcel] Grossmann wrote me that his examination was the best among all his comrades. He is quite a man, an excellent sailor, unpretentious and reliable" (*see* letter to Michele Besso, January 5, 1924; Einstein Archives 7-346.1).

The next crisis arose when Hans Albert courted a woman, Frieda Knecht (born in 1895), nine years his senior and holding a doctorate in German philology from the University of Zurich. Both Mileva and Einstein strenuously objected to the match. Einstein cited the woman's age; he also claimed that her short stature was due to dwarfism, and that she might be tainted by her mother's mental illness. At age twenty-three, Hans Albert defied his parents—as Einstein had earlier defied his—and married Frieda in 1927, a fact to which Einstein bitterly resigned himself. The relationship between father and son normalized somewhat, however, as Einstein became the grandfather of three grandchildren over the next twelve years.

In the United States, Hans Albert first worked as a research engineer at the Agricultural Experiment Station in Clemson, South Carolina, and, beginning in 1943, the year he became a U.S. citizen, at Caltech in Pasadena. He moved to Berkeley with his family in 1947, where he worked as a professor of hydraulic engineering at the University of California until his retirement in 1971. Celebrating his son's birthday near the end of his own life, Einstein praised him as having "inherited the main feature of my own character: the ability to rise above mere existence by persistently dedicating oneself to the best of one's ability to an impersonal goal" (*see* letter to Hans Albert Einstein, May 11, 1954; Einstein Archives 75-918).

Frieda died in 1958 at the age of sixty-three, after Evelyn had returned to the United States from boarding school in Switzerland, where her brother Bernhard lived. One year later, Hans Albert married Elizabeth Roboz (1902–1995), a neurochemist who did pioneering work on multiple sclerosis. She taught and did research at the University of Wyoming, Georgetown University, National Institutes of Health, and Stanford University. Hans Albert Einstein died of a heart attack at the age of sixty-nine in 1973 in Woods Hole, Massachusetts, while attending a symposium there. He was buried in Martha's Vineyard, Massachusetts.

The following three entries discuss Hans Albert's three children—Bernhard, Klaus, and Evelyn.

BERNHARD EINSTEIN—WIVES: AUDE ASCHER; DORIS SCHWEIZER

Bernhard Caesar Einstein was the oldest of Hans Albert and Frieda Knecht Einstein's three children. He was born on July 10, 1930, in Dortmund, Germany, and immigrated to the United States with his parents and younger brother in 1938. They lived in South Carolina until his father obtained a position at Caltech in Pasadena in 1943. In 1947 the family, which now included sister Evelyn, moved to Berkeley, where Hans Albert continued to work until his retirement.

Bernhard apparently was not a serious student in high school, but he still managed to be accepted into the University of California at Berkeley. In 1954, he left school and enlisted in the U.S. Army, doing his basic training at Fort Ord, California. While stationed in southern Germany, he met Aude Ascher, and they married the same year. After he was discharged from the army, they moved to Switzerland, back to Bernhard's family roots. He enrolled at the ETH (Federal Institute of Technology) in Zurich, and, like his grandfather before him, studied physics there. He took courses from Wolfgang Pauli, among others, and obtained an undergraduate degree. He returned to the United States and worked as a physicist and engineer in industry in both northern and southern California. An expert in electron tube technology and light amplification devices for night vision, he held five U.S. patents.

Bernhard met his grandfather as a young boy, and later they shared a love of sailing and music. As stipulated in Einstein's will, he bequeathed Bernhard his violin. Bernhard and Aude, who was a physician at the University of Zurich, had five children. After a long marriage, they divorced, and in 1998 Bernhard married Doris Schweizer, a ceramic artist.

Bernhard died of vascular disease and renal failure in Bern on September 30, 2008, at the age of seventy-eight. His son, Paul, a violinist, inherited the violin.

It is difficult to find information on Bernhard and Aude's five children and their several grandchildren, and they have not tried to capitalize on their famous name. The only fairly complete source of information is an article, "Children of a Lesser God," published by Michele Zackheim in *Discover* magazine in March 2008 (or February 12 in the online version).

KLAUS EINSTEIN

Einstein's grandson Klaus Martin Einstein was born in Zurich in 1932. The little boy died in South Carolina in early January 1939 of diphtheria, soon after he immigrated to the United States with his parents. In a letter of January 7, 1939, Einstein expressed his condolences to his son and daughter-in-law: "The deepest sorrow loving parents can experience has come upon you. Everything I observed of your little son indicated he was becoming a well-balanced and self-assured person with a healthy outlook on life. He exuded a happy and sunny disposition. Although I saw him only for a short period of time, he was as close to me as if he had grown up near me" (Einstein Archives 75-904).

EVELYN EINSTEIN—HUSBAND: GROVER KRANTZ

Granddaughter of Albert Einstein, Evelyn was born in Chicago in March 1941 and was adopted as an infant by Hans Albert, Einstein's older son, a research engineer for the Department of Agriculture in South Carolina at the time, and his wife Frieda Knecht, a Swiss national. Evelyn was very close to her mother, who died when she was seventeen, and had an unhappy relationship with her stepmother, Elizabeth Roboz, Hans Albert's second wife.

Evelyn was fourteen when her grandfather died. She had grown up in Berkeley but received her secondary-school education at a boarding school in Ftan, Switzerland. While there, she exchanged a number of affectionate letters with her grandfather, in which he encouraged her curiosity about the world and challenged her thinking and outlook. She claimed that these letters to her were lost through theft at Ftan. On one occasion, while visiting her daughter at the school, Frieda supposedly confirmed to the headmaster that Evelyn was the natural child of Albert Einstein and a dancer he met in New York. The Swiss physicist, Res Jost, who never revealed his source, further corroborated this information. Evelyn learned of this story but was unable to confirm through DNA evidence or otherwise that Albert was her father.

After finishing school in Switzerland, Evelyn, like her brother, attended the University of California at Berkeley, where she received a degree in German and Comparative Literature. She went to graduate school to obtain a doctorate in the comparative literature of the Middle Ages, specializing in myths and Arthurian legends. Her marriage in 1964 to Grover Krantz, an anthropologist who became known for his research on Bigfoot, ended in divorce. Unable to return to graduate school for financial reasons, Evelyn settled for a Master's degree in medieval literature, then supported herself through a number of professions, including police work at the Berkeley marina and working with animals, both as a hobby and as a paid

trainer, animal control officer, and veterinary technician. For many years, she served as a deprogrammer and counselor to individuals who sought to leave cults. Like her grandfather, she was sensitive to the plight of the powerless and contemptuous of those who abused their authority. She died of multiple medical conditions on April 13, 2011, at the age of seventy.

Source for Evelyn as natural child of Einstein: Gina Zangger, personal communication.

EDUARD EINSTEIN

Eduard, the younger son of Albert and Mileva, affectionately called “Tete,” “Tetel,” or “Teddy” by his family, was born in 1910 in Zurich. Though often gravely ill and fragile in early childhood—once, at age four, he was bedridden for seven weeks—he became an excellent student and was especially interested in the arts, composing poetry and playing the piano.

Because father and son could not seem to connect emotionally after the boy’s early years, Eduard engaged his father in discussions on music and philosophy, which Einstein said showed him that he was “racking [his] brain about the important things in life.” His goal, however, had been to study medicine and become a psychiatrist. This endeavor was cut short when Eduard’s physical and emotional frailty proved overwhelming as he entered his twenties. Einstein, belonging to a generation that was contemptuous of weakness and ill health, had a difficult time reconciling himself to his son’s condition. While believing that Eduard might have greater intellectual potential than his brother, Einstein lamented the younger boy’s lack of equilibrium and sense of responsibility: “He is an interesting little fellow, but he will not have an easy time in life” (see letter to Mileva Einstein-Marić, August 14, 1925; Einstein Archives 75-963). In October 1932, Eduard was hospitalized in the psychiatric clinic in Burghölzli near Zurich, and in 1933, he was diagnosed with schizophrenia. During the years he did not need intensive care, Mileva was his main caretaker at home. After her death in 1948, his legal guardian made other arrangements for him until he needed hospitalization again. He spent a total of about fourteen years under semiprivate care at the clinic, including the last eight years of his life and one year during Mileva’s own illness.

Eduard had been able to retain a lifelong interest in music, art, poetry, and Freudian psychiatry despite his many illnesses. As a young adult, he visited his father infrequently, though their correspondence was quite lively and reflected Einstein’s concern for his son’s condition. Shortly before his departure for America in 1933, Einstein made what turned out to be his final visit to Burghölzli. Eduard and Mileva remained in Switzerland, while Hans Albert and his family emigrated later.

Father and son would never see each other again. Eduard died in Burghölzli of a stroke in 1965 at the age of fifty-five. He is buried in the Höggerberg Cemetery in Zurich.

*Sources: CPAE, Vols. 5, 14; Highfield and Carter, *Private Lives of Albert Einstein*; Barbara Wolff, personal communication.*

Family No. 2 (Consisting of Einstein, Elsa, and Elsa’s Two Daughters)

ELSA LÖWENTHAL NÉE EINSTEIN—SECOND WIFE

Elsa Einstein was born in 1876 in Hechingen, Germany. She was one of three daughters of Rudolf Einstein, a textile manufacturer, and Fanny Koch, the sister of Einstein’s mother, Pauline. Elsa was Einstein’s first cousin maternally and second cousin paternally (see [fig. 17](#)). Because of the family connections, Einstein and Elsa saw each other frequently as young children, but then lost contact until they met again in 1912 in Berlin.

In 1896, Elsa married Max Löwenthal (1864–1914), who, like her father, was in the textile business. The following year, their first daughter, Ilse, was born, and Margot was born in 1899 ([fig. 23](#)). Another child, a son, was born in 1903, but the baby died soon after birth. Elsa divorced Max in 1908 and moved to Berlin with the girls (Max died in 1914). In 1912, during Einstein’s visit to Berlin, the two cousins became reacquainted. Einstein found Elsa’s sunny and outgoing disposition a marked and welcome contrast to Mileva’s. They started a long-distance relationship through

correspondence, and it soon became romantic, if not passionate. “We will give each other the gift of stability and an optimistic view of the world,” he wrote to her already the next year (October 10, 1913, *CPAE*, Vol. 5, Doc. 476; Einstein Archives 72-296). Elsa did nothing to discourage her married cousin, and in time she and her parents put pressure on him to divorce Mileva, for she felt that their open affair would hurt her daughters’ chances of finding proper suitors. Though Einstein’s love for Mileva had vanished, he still felt obligations toward his sons and responsibility for the family’s welfare. He told friends that he had no intention of actually marrying Elsa, but he continued to enjoy her company, including her daughters (fig. 24). This did not prevent him from making advances on Elsa’s daughter Ilse and even earlier developing a romantic interest in Elsa’s younger sister, Paula. Not until 1919 was this tangle of family relationships resolved. He finally divorced Mileva in February 1919 and married Elsa in June of that year.



FIGURE 23. Ilse and Margot Einstein in 1912, the year their mother, Elsa, and Einstein became reacquainted. (Gift of Eva Kayser)



FIGURE 24. Einstein and Elsa vacationing with daughters Margot and Ilse, July–August 1915, in Sellin on the island of Rügen (see [map 1](#)). (Gift of Eva Kayser)

The marriage seems to have been fairly platonic. Elsa took on the role of domestic partner, caretaker, and gatekeeper. Her bourgeois sensibilities helped to guide Einstein through the social whirl of Europe's academic communities, and she was openly proud to be the wife of a world-famous man, standing happily at his side during public appearances. Although Elsa was aware of Einstein's affairs, she seemed to place more importance on retaining her status as Einstein's wife; and on occasion, if reluctantly, she even enabled his liaisons (see *Romantic Interests*, *below*).

Shortly after Einstein and Elsa immigrated to the United States in October 1933, they received word that Ilse was terminally ill with tuberculosis. Elsa returned to Paris, where Ilse and her husband now lived with Margot, to be at her daughter's side during her last days in July 1934. Elsa never recovered from this grave loss. After seventeen years of marriage to Einstein, she died a painful death on December 20, 1936, of myocarditic exophthalmic goiter and lobar pneumonia, according to her death certificate (Einstein Archives 29-170), though she had also suffered from kidney problems. Einstein had cared for her with devotion during her last months, then became more secluded and "bearlike" after her death because, he admitted, she "was more attached to human beings than I" (see letter to Max Born, undated; Einstein Archives 8-199).

ILSE LÖWENTHAL EINSTEIN—HUSBAND: RUDOLF KAYSER

Ilse Löwenthal ([fig. 25](#)) was born in 1897 in Hechingen, Germany, to Elsa and Max Löwenthal. Her younger sister, Margot, was born two years later. Her parents divorced in 1908 when she was eleven years old, and mother and daughters moved to Berlin. In Germany it was customary for divorced women to revert to their maiden names, and Elsa began to do so at that time. Her name was Einstein as well, thus she was Elsa Einstein even before she married Albert. The girls seem to have adopted the name as well, since Ilse's schoolbooks were inscribed as "Ilse Einstein." Margot changed her name officially at about age twenty, as noted in a reissued birth certificate. Therefore, even though Ilse and Margot became Einstein's stepdaughters when he married Elsa in 1919, there is no evidence he ever legally adopted them and

gave them *his* last name, which biographers have often assumed. Still, he regarded the young women as family and treated them with affection.

Ilse, who had a prosthetic eye, possibly from an accident, became Einstein's first private secretary when he assumed the directorship of the Kaiser Wilhelm Institute for Physics in Berlin. Photos of her reveal a very pretty and stylish young woman. Before he married Elsa, Einstein had been sufficiently attracted to Ilse to have considered marrying her instead of her mother, a situation he did not hide from Elsa, who was willing to step aside if her daughter was in love with Einstein. Ilse poured her heart out about the dilemma in a letter of May 22, 1918, to family friend Georg Nicolai, a physician and antiwar crusader (*see Friends*). The long, hand written letter shows that Ilse was clearly confused by Einstein's love for her, but acknowledged that "I have never wished nor felt the least desire to be close to him physically. This is otherwise in his case—recently, at least. He even admitted to me once how difficult it is for him to keep himself in check" (*CPAE*, Vol. 8, Doc. 545; Einstein Archives 82-531). She confessed that she had gotten used to thinking of Einstein as a father figure. Ilse asked Nicolai to destroy the letter after he read it, but he did not heed her request. The letter is today in the Nicolai collection at the Institut für Zeitgeschichte (Institute for Contemporary History) in Munich. Einstein married Elsa the following year, and Ilse continued to work as his secretary.



FIGURE 25. Ilse Einstein.

Ilse married journalist Rudolf (Rudi) Kayser (born 1889), the editor of the Berlin monthly (today quarterly) literary journal *Die Neue Rundschau*, in 1924. Einstein affectionately referred to the couple as “Rudilse.” Rudolf also became an early Einstein biographer (see Biographies in [appendix A](#)) under the pen name “Anton Reiser.” He and Ilse left Berlin and went into exile in Paris in 1934 following the rise of Hitler. Rudolf was instrumental in rescuing Einstein’s papers and correspondence from Berlin, to be shipped to the United States via France. He was heartbroken when Ilse died of tuberculosis that same year at age thirty-seven, shortly after Elsa arrived at her bedside. The widowed young man immigrated to the United States the following year after a short stint with the Querido Publishing House in Amsterdam

and became a professor of German and European Literature at Brandeis University near Boston. He married Eva Agathe Urgiss (born 1911 in Berlin), the daughter of the German-Jewish screenwriter, musician, and film critic Julius Urgiss, in 1936. Rudolf died in New York in 1964. Eva died in 1999.



FIGURE 26. Margot Einstein.

MARGOT LÖWENTHAL EINSTEIN—HUSBAND: DMITRI MARIANOFF

Margot Einstein ([fig. 26](#)), the second daughter of Elsa and Max Löwenthal, was born in Hechingen, Germany, in 1899. Following her parents' divorce in 1908, she moved

with her mother and older sister, Ilse, to Berlin. She was always small and shy and remained very much under her mother's influence even in adulthood, to her husband's chagrin. Ilse was her mother's favorite, but Margot as a child was Einstein's favorite. She married Dmitri Marianoff in 1930.

Margot came to the United States in 1934 after her sister's death and studied sculpture at Columbia University. Her husband, a Russian émigré, remained in Paris until at least 1935, after which he became attached to the Soviet Embassy in New York for unknown reasons. Some believed he was a spy. He wrote a biography about Einstein that Einstein regarded with disdain, stating angrily that Marianoff had no moral authority to write about his life. Separated from her husband in the United States, Margot eventually moved into her stepfather's house in Princeton and became well known in town for her small, delicate bronze sculptures. She divorced Marianoff in 1937 and became a U.S. citizen in 1940, at the same time as Einstein. She was close friends with Helen Dukas, the only other person still living in Einstein's house after Elsa's death in 1936, Maja Winteler-Einstein's death in 1951, and Einstein's death in 1955. Both continued to live there until their own deaths. Margot, who never remarried and had no children, died in 1986 in Princeton, four years after Helen Dukas.

Friends

(See also [Part II](#), Assistants; Collaborators; Colleagues)

Michele Besso

Michele Besso (1873–1950) was Einstein's closest and oldest lifelong friend. The two became acquainted at a musical evening in 1896 when Einstein entered the Swiss Federal Polytechnical School (ETH) in Zurich and Besso worked at an electrical machine factory close by in Winterthur. In 1904, Einstein helped Besso secure a position at the Swiss Federal Patent Office in Bern. There they continued to meet and talk regularly about physics. Einstein acknowledged Besso's significant help in his seminal paper on special relativity in 1905. Still unable to unravel the contradiction between the relativity principle and the fact that light appeared to have the same velocity in whatever frame it was viewed, Einstein paid Besso a visit one day. During their conversation, Einstein reached the fundamental insight concerning what he came to call "the relativity of simultaneity." He realized that it was possible to reconcile the two principles of his theory if one recognized that different inertial observers in motion with respect to each other might disagree about the timing of distant events. Besso is thus one of the few nonprofessional scientists to have played a role in the development of twentieth-century physics. He himself would compare his contribution to that of a sparrow that had been borne aloft by an eagle (see letter from Michele Besso, April 21, 1950; Einstein Archives 7-198).

Einstein greatly prized Besso's human qualities. He assigned to Besso the delicate task of accompanying Mileva and the boys from Berlin to Switzerland after the breakup of the Einstein family on the eve of the First World War. Together with Heinrich Zangger, Besso served as mediator between the estranged couple during their separation and as an unofficial guardian of the Einstein boys during the difficult years of their adolescence.

After Einstein left Switzerland, the two men corresponded frequently about scientific matters, and Besso always remained interested in the further development of relativity theory, following the development of the general theory closely. Besso's fascination with religious questions in later life was not shared by his friend. After Besso's death, Einstein remarked in a letter to his family: "Now Besso has departed from this strange world a little ahead of me. That means nothing. People like us, who believe in physics, know that the distinction between past, present, and future is only a stubbornly persistent illusion" (letter to Vero and Bice Besso, March 21, 1955; Einstein Archives 7-245).

Kurt Blumenfeld

See [Part III](#), Jewish Identity and Ties, "Catalyst".

Max and Hedwig Born

Max Born (1882–1970), originally from Breslau (today, Wrocław in Poland), was a close friend as well as colleague of Einstein from the early days of Einstein's time in Berlin. Thereafter, he and Einstein maintained a long correspondence that is a valuable source of information for Einstein's life and work. Born was one of the leading theoretical physicists of the interwar years and a professor in Berlin, Frankfurt, and Göttingen. When Born was considering whether to take up a new position, Einstein advised him, "Theoretical physics will flourish wherever *you* happen to be" (see letter to Born, March 3, 1920, *CPAE*, Vol. 9, Doc. 337; Einstein Archives 8-146). His best-known contribution was to elucidate the statistical interpretation of the new quantum mechanics theory in the mid-1920s. He played an important role in the development of both versions of quantum mechanics, that of the matrix (of Werner Heisenberg) and of the wave equation (of Erwin Schrödinger). Born was awarded the Nobel Prize for this work, in 1954. Since his contributions to this area focused on a masterly understanding of the statistical approach to physics, an approach often associated with Einstein, it came as a surprise to Born, and to others among Einstein's friends, when Einstein refused to accept the new theory. This was even more puzzling as it seemed to vindicate positions that Einstein had previously taken, such as the wave-particle nature of light.

Born and Einstein held somewhat similar political views, both being more liberal and democratically minded than the typical German academic of the interwar period. During the German revolution of November 1918, which deposed the Kaiser, Einstein was asked to intercede with revolutionary students who had imprisoned leading officials of the University of Berlin, including the rector. Born and another colleague accompanied him. Thanks to Einstein's well-known opposition to the recent war, the three gained entry into the Reichstag, where the Council (Soviet) of Students was meeting. The students were taken aback when Einstein criticized their actions as infringing on traditional liberties of the universities. Recognizing that it lacked the requisite authority in the matter, the council directed the three men to the seat of government in the nearby Wilhelmstrasse, where Friedrich Ebert, the newly appointed German chancellor, hastily scribbled a note with instructions to free the dignitaries. In commenting on the incident later, Born recalled the naive hope of the three friends that they had just witnessed the last of Prussian autocracy and the dawn of a new, democratic Germany (see G. Born, ed., *Born-Einstein Letters*, pp. 147–148).

Born was of Jewish descent, though his family was largely assimilated. His outlook on Jewish affairs was quite different from that of Einstein, who became a cultural Zionist after the First World War and opposed assimilationism. Born's wife, Hedwig, came from a partly Jewish background. She was a close friend of Einstein as well, and she often exchanged playful doggerel with him in their correspondence. The Borns' very different views from Einstein's on how Jews should conduct themselves in German society emerged during the anti-relativity campaign in autumn 1920 (see [Part II](#), Relativity Theory, "Anti-Relativity Campaign"). Both Borns were appalled at the prospective publication of a book titled *Conversations with Einstein* by a German-Jewish author, Alexander Moszkowski (see [appendix A](#), Biographies). Hedwig Born launched an intense private campaign to convince Einstein to withdraw permission to publish the book, fearing that Moszkowski's hero worship of Einstein would lend credence to the accusations of the anti-relativists that Einstein was a publicity hound. Einstein, on the other hand, considered it cowardly and counterproductive to hide one's Jewishness in public.

Ultimately, the families of both men had to flee Germany when the Nazis came to power. Max and Hedwig Born moved to England and remained in exile until, in retirement, they finally returned to Germany, where Max lived when he received word of his Nobel Prize in 1954. The Borns were the grandparents of British-born Australian singer and actor Olivia Newton-John. (See also G. Born, ed., *The Born-Einstein Letters*, and M. Born, *My Life and My Views*.)

Gustav Bucky

See [Part II](#), Collaborators.

Lucien Chavan

Chavan (1868–1942) was Einstein's pupil and friend. A native of Lausanne, he and Einstein met in Bern, where from 1903 until 1908 Chavan was technical secretary in the Federal Postal and Telegraph Administration. While in Bern, he received private instruction from Einstein in mathematics and electrotechnical subjects, which was crucial for his promotion to electrotechnician, first class, at the end of 1908. Prior to his promotion, he may also have audited Einstein's course in molecular theory of heat in the summer semester at the University of Bern. When a superior at the Postal Administration obstructed Chavan's further advancement at his workplace, Einstein organized the superior's removal, complaining about harassment to Ludwig Forrer, the Swiss minister (*Bundesrat*) for postal affairs (see letter to Chavan, July 5–6, 1911, *CPAE*, Vol. 5, Doc. 271; Einstein Archives 37-562). After his retirement in 1921, Chavan worked for ten years in a physics laboratory in Geneva while attending courses in mathematics and physics at the university there. Chavan's wife, Jeanne Chavan-Perrin, was a close friend of Mileva's, and the two families socialized frequently.



FIGURE 27. Einstein at the Swiss Patent Office in Bern, ca. 1905. (Photo by Lucien Chavan)

Chavan was the individual who took the two well-known “patent office” photos of Einstein in Bern, though the year was probably not 1905, as often claimed, nor was the photo actually taken at the patent office ([fig. 27](#)).

Jakob Ehrat

Ehrat (1876–1960) was a classmate and friend of Einstein. The son of a baker from Schaffhausen, he began his studies at the University of Zurich, switching to the department of engineering at the ETH in his second semester in 1897. The following year he became Einstein’s classmate in the department of mathematics and physics at

the ETH (“our intellectual boot camp”; letter to Ehrat, May 12, 1952; Einstein Archives 88-049). After graduating in 1900 with a concentration in mathematics, he served as *Assistent* at the ETH and accepted a temporary position at a boarding school in Germany. From 1910 to 1945, he was an instructor in mathematics and accounting at a *Gymnasium* in Winterthur. In 1914, Einstein tried, unsuccessfully, to play matchmaker for him and a widowed daughter of the Winteler family; that same year he married Margrit Schmidt. In 1952, after Ehrat complained of his failing eyesight and inquired after Einstein’s health, Einstein responded in a letter dated May 12, noting his own liver and stomach ailments. Yet he wrote that he was quite content, “as I have triumphantly survived the Nazi period and two wives.”

Paul Ehrenfest

Paul Ehrenfest (1880–1933) was an Austrian physicist who eventually settled in the Netherlands. He was one of Einstein’s closest friends for many years, and their friendship was based on more than a love of physics: they had a true and abiding affection for each other and their respective families. He assured Einstein that he was welcome in Leyden at any time, and particularly as a professor of theoretical physics, because there “we have nothing but people who love *you*, not just your cerebral cortex” (see letter from Ehrenfest, September 8, 1919, *CPAE*, Vol. 9, Doc. 101; Einstein Archives 9-431).

Ehrenfest had studied in Vienna under Ludwig Boltzmann but, like many Jews at the time, had struggled to find a permanent academic position. He visited Prague in early 1912, not only to meet Einstein but also to offer his own candidacy for Einstein’s soon-to-be-vacated chair at the university. As an uncompromising atheist, however, Ehrenfest was out of contention, as the Austro-Hungarian emperor insisted that all university personnel declare some religious affiliation. Einstein found Ehrenfest’s unbending position unrealistic, but Ehrenfest stuck to his guns. Later in 1912, at H. A. Lorentz’s recommendation, Ehrenfest succeeded Lorentz to the physics chair at Leyden in the Netherlands, even though Einstein had been the physics department’s first choice.

Although he was a distinguished researcher, Ehrenfest was perhaps more influential as a mentor, critic, and supporter of others, and he was an exceptional teacher. Einstein described him as the best teacher he had ever known in their profession. His penetrating insights were especially attractive to Einstein. The two men first met during Einstein’s sojourn in Prague in 1912 while Ehrenfest was scouring Europe for a position at a university. Einstein unsuccessfully recommended him as his successor in Prague. After Ehrenfest’s move to Leyden and Einstein’s move to Berlin, Einstein made regular visits to the Dutch city and became very close to Ehrenfest and his family (Ehrenfest’s wife Tatyana was a distinguished mathematician). Their correspondence over many years is generally the best record of Einstein’s scientific thinking until the time of Ehrenfest’s death.

In the late 1920s, Ehrenfest became increasingly prone to depression. This was at least partly due to the difficulty he experienced in keeping up with the dramatic changes in physics brought about by the discovery of quantum mechanics, though in fact he made major contributions in statistical mechanics during this period. He was despondent at the growing strength of Nazism in Germany that affected his friends in that country, and was wracked with guilt because of an affair he was having. Finally, in 1933, he took his own life, after first killing his son Vassily (“Wassik”), who suffered from Down syndrome, in the waiting room of the institute where the son was being treated. He left behind his wife, two daughters, and another son. (See Klein, *Ehrenfest*.)

Elisabeth, Queen of the Belgians

Einstein first met Queen Elisabeth when he visited his uncle, Caesar Koch, in Belgium in 1929 and was invited to the royal palace at Laeken. The queen was something of an intellectual and enjoyed good conversation and good music, so Einstein brought his violin with him, as always hoping for an opportunity to play it. Together with a lady-in-waiting, they had tea and then played in a musical trio, and the queen and Einstein felt an immediate rapport. He visited her and her husband, King Albert, again a year later after a trip to London. This friendship became extremely important

to Einstein in 1933, when he sought refuge from Nazism before immigrating to the United States. The king and queen provided Einstein and Elsa temporary housing in the seaside village of Le Coq sur Mer (De Haan), as well as security guards. Though he never saw her again after 1933, Einstein corresponded with Elisabeth until the end of his life, often recalling the wonderful time he had had in Laeken. In his letters he always addressed her as “Dear Queen.”

Elisabeth was born in 1876 in Possenhofen to a Bavarian duke, Karl Theodor, and his wife, Maria Josepha, a Portuguese *infanta* (princess). She married Prince Albert of the Belgians in 1900, and became Queen of the Belgians when Albert became king upon the death of his uncle, the notorious Leopold II, brutal exploiter of the Congo, in 1909. They had three children. Albert died in a mountain-climbing accident in the Ardennes in 1934, just a year after the Einsteins’ last visit. Elisabeth remained intellectually active all her life and promoted her love of the arts. During the German occupation of Belgium from 1940 to 1944, she used her influence as queen and her German connections to stop the deportation of hundreds of Jewish children by the Nazis. She was later awarded the title “Righteous among the Nations” by the Israeli government. She died in 1965 at the age of eighty-nine.

Marcel Grossmann

Marcel Grossmann (1878–1936) was a close friend of Einstein’s during their college years and afterward. Grossmann’s lecture notes at the ETH, which were careful and complete, served as a “lifeline” for Einstein when he skipped classes (see “Remembrances,” no. 208 in [appendix C](#)). Einstein’s doctoral dissertation is dedicated to “My friend, Dr. Marcel Grossmann.”

Though born in Budapest, the son of a factory owner, Grossmann and his family were originally from Höngg, on the outskirts of Zurich, and Swiss nationals. He attended the first years of *Gymnasium* in Budapest, but came with his family to Basel, Switzerland, when he was fifteen, entering the ETH in 1896 at the same time as Einstein. During their student days, they would meet every few weeks for iced coffee at the Grand Café Metropol in Zurich. After graduation, Grossmann was instrumental in helping Einstein obtain a position with the Swiss Federal Patent Office in Bern, as Grossmann’s father was friendly with the director. As a young husband and father, Einstein deeply appreciated this favor. Grossmann, however, played an even more critical role in helping Einstein later on, after Einstein had already become a distinguished physicist, during the period when they were colleagues at the ETH in Zurich. Both held chairs there, Einstein in physics and Grossmann in mathematics, specifically in descriptive geometry. Einstein, who returned to Zurich in 1912 after a year in Prague, had realized by this time that his general theory of relativity would require mathematical expression in a formalism that described four-dimensional curved geometries. He turned to his old friend Grossmann to inquire if such a formalism existed. According to an acquaintance, he approached Grossmann with the words, “Grossmann, you must help me or else I’ll go crazy!” (as quoted in Sauer, “Marcel Grossmann and His Contributions to the General Theory of Relativity”). Grossmann proceeded to educate Einstein in the intricacies of Riemannian geometry and the absolute differential calculus, which form the underpinning of general relativity. So critical was Grossmann’s role in the work that the early development of the theory was actually a collaboration by the two men. The two friends jointly published the so-called *Entwurf* (“outline”) theory of gravity, which is a precursor to general relativity. By then Einstein had achieved proficiency in the mathematical language in which the theory is couched. After his move to Berlin in 1914, the further development of the theory did not require Grossmann’s input. Nevertheless, so significant was Grossmann’s role in the history of modern gravitational theory that an important international series of conferences convenes in his honor.

In 1930 Grossmann took issue with Einstein’s latest work on a unified field theory (see the last section in [Part II](#)), the teleparallelism approach. He tried to make the incorrect argument that Einstein based his approach on a faulty construct in the mathematical theory of geometry, which was Grossmann’s own specialty. The two friends corresponded on the subject before Grossmann wrote a paper detailing his criticisms. Einstein refused to reply in public, perhaps because he suspected that Grossmann’s erroneous reasoning might be explained by the mysterious illness that had begun to afflict him shortly after their earlier collaboration concluded.

Eventually, this illness was correctly diagnosed by their mutual friend, Heinrich Zangger, as multiple sclerosis, and it led to Grossmann's death at the relatively young age of fifty-eight. Einstein movingly wrote to Grossmann's widow about his many debts to Grossmann, ending the letter with "one thing is beautiful. We were friends and remained friends for life" (letter to Anna Grossmann-Keller, September 26, 1936; Einstein Archives 11-515).

Conrad Habicht

Habicht (1876–1958) was a friend and fellow member of the Olympia Academy, an informal philosophical discussion group organized in Bern by Einstein and Maurice Solovine in 1903 (see [Part III](#), Organizational Ties). A native of Schaffhausen in Switzerland, Habicht pursued studies in mathematics in Munich and Berlin before coming to the University of Bern. He had met Einstein in his hometown of Schaffhausen in 1901, when the latter was teaching at a private school there. After receiving his doctorate in mathematics the following year, he taught mathematics and physics at a Protestant school in Schiers, canton of Graubünden, for the next decade. Habicht corresponded regularly with Einstein in this period. He was the recipient of the famous letter of May 1905 in which Einstein promised him four papers in differing stages of completion: the light quantum hypothesis that he refers to as "very revolutionary"; two on molecular dimensions and Brownian motion; and a fourth that is a rough outline for an electrodynamics of moving bodies (special theory of relativity). The last, he wrote, will require a modification in the concept of space and time (see letter to Habicht, May 18 or 25, 1905, *CPAE*, Vol. 5, Doc. 27; Einstein Archives 12-420). This groundbreaking paper was published five or six weeks later. Shortly before transferring to the cantonal school in Schaffhausen, where he taught physics and mathematics from 1915 until 1948, Habicht married Anna Kehlstadt. During the last twenty years of his life, he was the director of the Schaffhausen Musikkollegium, where he played the violin. (See also [Part II](#), Collaborators.)

Hans Mühsam

Mühsam (1876–1957), a friend and sometime collaborator of Einstein's, was a physician and ardent Zionist, born in Berlin. Already as a youth in Lübeck, he suffered from the taunts of anti-Semitic schoolmates. Mühsam began his medical career in 1900 with an appointment at the Jewish Hospital in Berlin. In 1906, he was elected head of a group of Russian refugees with Zionist leanings who provided housing for transient Jews. In the following years, as a member of the board of directors of the Society of Jewish Natural Scientists and Physicians for Sanitary Conditions in Palestine, he devoted efforts toward eradicating malaria in Palestine and was one of the organizers of what later came to be known as the Pasteur Institute in Jerusalem.

In 1915, Mühsam treated Einstein's mother for cancer and he became fast friends with her grateful son. The first presentation copy of Einstein's *On the Special and General Theory of Relativity (Gemeinverständlich)* (1917) is dedicated to Mühsam, who was about to leave for the front in France as a battalion surgeon. Einstein biographer Abraham Pais writes that Einstein confided to Mühsam, his closest friend during the Berlin years, that, as a schoolboy, he would compose songs in honor of God while walking to school. After the war, Mühsam married Minna Adler and practiced medicine in the Charlottenburg district of Berlin. Together with Einstein, he developed a viral filter in 1923, about which they wrote a detailed paper published in the *Deutsche Medizinische Wochenschrift* the same year. In June of that year, Einstein hired Mühsam's foster daughter, Betty Neumann, as a temporary secretary. A romance blossomed (see [Romantic Interests](#)), which strained his good relationship with the Mühsams to the breaking point. The friendship was renewed through the good offices of their mutual friend, the artist Hermann Struck. The Mühsams immigrated to Palestine in 1938, settling on Mount Carmel near Haifa. In summer 1942, Einstein wrote Mühsam that he had "become a lonely old chap who is mainly known for not wearing socks and who is exhibited as a curiosity on special occasions" (June 15, 1942; Einstein Archives 38-337). After Hans was stricken with Parkinson's disease, he dictated his last letters for Einstein to Minna. He died in 1957. (See also [Part II](#), Collaborators.)

Otto Nathan

See Archives.

Georg Nicolai

Nicolai (1874–1964) was born Georg Lewinstein in Berlin. He was Titular Professor of Physiology at the University of Berlin and Senior Physician at the Charité Hospital, specializing in cardiology. He presumably met Einstein while treating the latter's cousin and future wife, Elsa, for a heart ailment. As a prominent pacifist and member of the Bund Neues Vaterland, Nicolai served as a mentor for Einstein's first, tentative steps in politics. The "Countermanifesto to the Europeans," which Nicolai drew up at the outset of the First World War, condemned the excesses of nationalism that led to the senseless brutality of war. Einstein signed the manifesto and apparently had a hand in its formulation (see [Part III](#), Political Contexts, "Manifesto to the Europeans"). Their collaboration cemented a bond of ideological kinship between the two men. Accused of treason during the war, Nicolai was imprisoned but managed to escape to Denmark. He returned to republican Germany at the end of hostilities and almost immediately infuriated the radical right with a proclamation protesting the murder in January 1919 of Spartacist leaders Karl Liebknecht and Rosa Luxemburg (Einstein also signed this appeal). Reappointed to a teaching position at the University of Berlin, he was forced out of it by anti-Semitic students and savage attacks in the right-wing press, against which Einstein protested in vain (see "In Support of Georg Nicolai," January 26, 1920, *CPAE*, Vol. 7, Doc. 32; Einstein Archives 78-124). Officially dismissed from his post by a committee of the university senate in February 1921, Nicolai left Germany the following year for Argentina, where he took a position as a professor of physiology at the University of Córdoba.

Einstein's respect for Nicolai's dazzling intellect and intellectual daring was tempered by resentment of his frequent importuning: in particular, Einstein felt manipulated by Nicolai's persistent requests that Einstein lend his name and funding to a publishing venture that Einstein considered hopeless (see letters to Georg Nicolai, ca. January 22, 1917, and February 28, 1917, *CPAE*, Vol. 8, Docs. 289 and 303; Einstein Archives 44-556 and 44-552). As a result, a tinge of bitterness remained between them. When Einstein visited Nicolai in 1925 on his trip to Latin America, he noted that the latter still had a big mouth and that in Córdoba, too, he was not taken seriously (see letter to Elsa and Margot Einstein, April 15, 1925, *CPAE*, Vol. 14, Doc. 474; Einstein Archives 143-186). In 1927, Nicolai left Córdoba for the university in Rosario, and in 1936, after living three years from hand to mouth, found a post at the University of Chile in Santiago. He died in Santiago in 1964.

An indication of Nicolai's ability to shock friend and foe alike is evident from an exchange he had in early 1918 with Einstein's older adoptive daughter, Ilse Einstein, a former lover. As Einstein was then mulling remarriage, Nicolai encouraged Ilse to marry Einstein, in spite of her family's expectations that mother Elsa was the bride-to-be (see Ilse Einstein's letter to Georg Nicolai, May 22, 1918, *CPAE*, Vol. 8, Doc. 545; Einstein Archives 82-531). Ilse declined and Einstein married Elsa the following year. (See also Zuelzer, *The Nicolai Case*, for a detailed biography of the man.)

Janos Plesch

Janos Plesch (1878–1957) was another of Einstein's several physician friends. Born in Budapest to a Jewish family, he became a medical practitioner in Berlin in 1903. He prided himself as the personal physician of the town's celebrities and academics, including the musicians Artur Schnabel and Fritz Kreisler and chemist Fritz Haber. Though he had an impressive academic and research background, he became better known for giving lavish parties, living in high style, and owning a fleet of expensive cars. Einstein first met Plesch in 1919, when he was caring for his mother, Pauline, during her terminal illness, and chose him as his own physician when he became gravely ill with heart problems in 1928. Plesch guided him to recovery, part of which took place at Plesch's palatial villa in Gatow, where Einstein enjoyed privacy in the lakes region of southwestern Berlin. It has been said that Plesch and Einstein enjoyed each other's ribald sense of humor. Einstein is reputed to have said "Plesch ist ein

Schwein, aber er ist mein Freund" (Plesch is a pig, but he is my friend).

Plesch and his family left Berlin in 1933 and moved to London, where he continued to practice medicine. After emigrating, Plesch played a role in the bizarre tale of Grete Markstein. This Viennese confidence trickster confronted Plesch in London and initially convinced him that she was an illegitimate daughter of Einstein's. What lent credence to her story, according to a letter he wrote his old friend, was the uncanny resemblance of Markstein's son to Einstein, who by then had already taken up residence in Princeton. Einstein claimed the whole affair was a swindle, which it was, but he "took the allegations seriously enough to call in a private investigator." The possibility that Einstein feared that "Lieserl" was stalking him cannot be dismissed (see Highfield and Carter, *Private Lives*, pp. 91–94; and Family, "'Lieserl' and the Search to Find Her").

Plesch retired to Switzerland and then moved to Mill Valley, California, after the death of his wife. He died in 1957 of a heart attack.

Romain Rolland

The most prominent pacifist of his generation, Rolland (1866–1944) left his native France for Switzerland during the First World War. He first met Einstein in 1915, when the two men discussed the unfolding European nightmare. He was awarded the Nobel Prize for Literature the same year for his ten-volume novel, *Jean Christophe* (1903–1912).

Initially, Rolland had studied philosophy at the École normale supérieure but received his degree in history in 1889. After a two-year sojourn in Italy, he returned to France and earned a doctorate with a dissertation on the history of early opera. He taught at various lycées in Paris, and in 1903 was appointed to the first chair of music history at the Sorbonne. He was not well suited for teaching, however. Convinced that he could make a living from writing, he resigned his university post in 1912.

In many ways, Einstein shared Rolland's immediate dilemma of discovering a means to achieve a permanent peace after the First World War that would preserve intact their nineteenth-century conception of the responsibility of the intellectual. In drawing up his "Declaration of the Independence of the Mind," Rolland conceived of an intellectuals' international that would be a voluntary association of artists and scientists, organized around supranational humanistic principles. Einstein attached his name without hesitation. One initial step in this commitment was the collaboration of both men in 1919 in drawing public attention to the plight of Eastern Europe as the Allied blockade created shortages in foodstuffs and medicines.

Though Rolland was one of the co-founders in 1919 of the Clarté movement, dedicated to a just postwar political order, he soon became estranged from the movement. This came about when one wing, led by co-founder Henri Barbusse, embraced the Third International in 1920, leading to the formation of the French Communist Party and precipitating a breach between Bolshevik and non-Bolshevik conceptions of internationalism. In 1920, Rolland published two more novels, *Pierre et Luce* and *Clérambault*, that stressed absolute pacifism, individualism, and defense of moral freedoms, all of which should remain above the political fray. He made no effort to link pacifism with existing organizations or to an international program of action.

Einstein renewed his collaboration with Rolland in 1930 when he agreed to write an essay for a planned publication encouraging intellectuals to band together to lend moral support to conscientious objectors (see letter to Romain Rolland, October 10, 1920; Einstein Archives 84-168). Einstein incurred Rolland's ire, however, with his "Two Percent Speech." Rolland complained in a letter of February 20, 1931, to H. Runham Brown that war will by no means be abolished if "two per cent of the population of the world refuse to fight. Einstein seems to overlook the fact that the technique of war has changed since 1914, and is still changing. The tendency has been to employ small armies of technicians who know how to run air squadrons armed with gas and bacteriological torpedoes and other weapons of mass destruction" (quoted in Nathan and Norden, *Einstein on Peace*, pp. 118–119). Rolland's disappointment was even greater when Einstein abandoned the cause of the conscientious objectors, writing that while the latter was a "genius in his science [he was] in every other field a fool" (see letter of Rolland to Stefan Zweig, September 15, 1933: Grundmann, *The Einstein Dossiers*, p. 272).

Rolland died at the end of 1944 in Vézelay, spending his last years in solitude during the German occupation of France.

Maurice (Moritz) Solovine

Solovine (1875–1958) was a friend and an original member of the Olympia Academy (see [Part III](#), Organizational Ties). He came from a Jewish merchant family in Botoșani, Romania, where he was educated at a humanistic *lycée*. Upon his arrival in Bern, Solovine matriculated in the philosophical faculty of the university in winter semester 1900, taking a wide range of courses. He began taking private lessons with Einstein in 1902, which were expanded into an eclectic philosophical discussion group, mockingly referred to as the Olympia Academy. Always quick to turn a phrase, Einstein referred to his friend as “Insolvini.” In 1904, he left Bern for Lyon in France, where he attended classes as an unregistered auditor and then as a regular student at the university; he formally exmatriculated from the University of Bern in 1905. The following year, he moved to Paris, where he assisted in editing the journal *Revue philosophique*. From 1920 to 1924, he published French translations of Einstein’s popular book on special and general relativity (*Gemeinverständlich*), *Geometry and Experience*, and *The Meaning of Relativity*. In the following years, he translated the works of a number of Greek philosophers, including Democritus and Heraclitus. In 1938, he translated Einstein and Leopold Infeld’s *The Evolution of Physics*. Finally, in the 1950s, he directed a series for the publishing house of Gauthier-Villars on “Science and Civilization” and “Masters of Scientific Thought.” The sense of camaraderie that Einstein shared with Solovine during their carefree if impoverished days in Bern was summed up a half century later in his paean to the Olympia Academy and to the “childlike joy with which it took delight in all that was clear and intelligent” (see letter to the immortal Olympia Academy, April 3, 1953; Einstein Archives 21-294).

Winteler Family

Einstein’s ability to expand the field of familial affection is evident in his relationship with the Winteler family, with whom he boarded while attending the Aargau Cantonal School in Switzerland. During the school year 1895–1896, Einstein lived in the home of Jost Winteler (1846–1929), his wife Pauline (1845–1906), and their seven children. His emotional attachment to them was so strong that he came to regard them as a second family, referring to Jost as Papa, and Pauline as Mamerl (Mommy) No. 2. Einstein took part in family discussions, outings, and musical evenings. The sixteen-year-old was particularly impressed by Papa Winteler’s deep-seated aversion to power politics, his freethinking, liberal spirit, as well as his pacifist beliefs. Some years later, Einstein acknowledged this influence, coining one of his most famous quotes in conscious dedication to his former *Hausvater*’s worldview: “Mindless obedience to authority is the greatest enemy of the truth” (see letter to Jost Winteler, 8 July 8, 1901, *CPAE*, Vol. 1, Doc. 115; Einstein Archives 29-457). In reflecting on Nazi excesses three decades later, he praised his friend’s foresightedness: “I think often of Papa Winteler and of the prophetic accuracy of his political views” (see letter to Maja Winteler-Einstein, August 31, 1935; Einstein Archives 29-417).

A native of the Toggenburg region of Switzerland, Jost did his doctoral work in philology between 1870 and 1875 at the University of Jena in Germany, during which time he married Pauline (1871). He had some short-lived appointments in Switzerland, including one at the Fribourg Cantonal School, where his liberal views forced him to resign. From 1884 until 1909, he taught Greek and history in the humanistic *Gymnasium* of the Aargau Cantonal School. Einstein, a pupil in the technical section, never had a class with him.

Einstein’s relationship with Pauline was particularly close. In addition to filial affection for his Mamerl No. 2, Einstein viewed her as a mother confessor. After beginning a romance with daughter Marie during his year in Aarau, it was to Pauline Winteler that he turned when his ardor for Marie had cooled. Once in Zurich, where he had met Mileva Marić at the ETH, Einstein asked Pauline for forgiveness for trifling with Marie’s affections. He wrote that he had to seek his fortune in hard work and the search for truth in God’s nature to avoid the snares of this world (see letter to

Pauline Winteler, May ?, 1897, *CPAE*, Vol. 1, Doc. 34; Einstein Archives 29-453). Beyond the pretext, Einstein genuinely regretted the grief he felt at abandoning his “little angel” and causing heartbreak to both mother and daughter.

On November 1, 1906, a mentally deranged son of the Winteler family, Jost Jr., shot to death his mother Pauline, brother-in-law Ernst Bandi, and then turned the gun on himself. A distraught Einstein wrote his former *Hausvater*: “Those who have experienced her goodness toward themselves and others, and with what seriousness she pursued truth and justice must tremble at the thought of what blind fate has wrought here.” He touched once more on the heartache he had caused in breaking off his relationship with daughter Marie (see letter to Jost Winteler, November 3, 1906, *CPAE*, Vol. 5, Doc. 41; Einstein Archives 29-460).

There were other family intersections, aside from Einstein’s relationship with Jost, Pauline, and Marie: his sister Maja married one of the Winteler sons, Paul; his best friend Michele Besso married the oldest Winteler daughter, Anna; and he played unsuccessful matchmaker for a widowed daughter, Rosa Bandi-Winteler, and his friend Jakob Ehrat.

Stephen Wise

Unusual among American Reform rabbis, Stephen Samuel Wise (1874–1949) was also a fervent Zionist. Einstein found Wise’s combination of social progressive and committed Zionist views most appealing, and it cemented the two men’s friendship once Einstein immigrated to the United States. “Above all, what I admire in him is his bold activity toward building the self-respect of the Jewish people, combined with profound tolerance and penetrating understanding for everything human” (“Tribute to Wise on his 60th Birthday,” March 1934; Einstein Archives 28-268).

Born in Budapest to a family of rabbis, Wise immigrated to New York City as an infant. Before completing his PhD at Columbia University in 1901, he served as honorary secretary of the Federation of American Zionists, a forerunner of the Zionist Organization of America, for which he served as president and vice president during his lifetime. Both organizations were dedicated to the founding of a “Jewish National Home in Palestine.”

Wise began his career as rabbi ministering to a congregation in Portland, Oregon. Here he acted on his belief in the unity of religious and public service by simultaneously serving as an officer of the Oregon State Conference of Charities and Correction, as well as Commissioner of Child Labor for the state. Before returning to New York in 1906, Wise was offered the position of rabbi at the prestigious Temple Emanu-El. He turned down the opportunity for fear of being constrained in speaking his mind, and in the same year, founded the Free Synagogue on the Upper West Side. Breaking with tradition, it offered free pews while maintaining an extensive program of social welfare.

In 1914, he co-founded and served on the board of the National Association for the Advancement of Colored People (NAACP) “to achieve equality of rights among all citizens.” Four years later, together with prominent Jewish leaders Louis Brandeis and Felix Frankfurter, he convened the American Jewish Congress (AJC), which in addition to its stated goals of equal rights for all sought to present a unified American Jewish position on Palestine at the Paris Peace talks of 1919. At the end of the 1920s, under Wise’s leadership the AJC became a powerful pressure group to advance Jewish interests. Wise remained its honorary president until his death.

Einstein made Wise’s acquaintance in 1933 after his own arrival in the United States, just as the situation of European Jewry became increasingly perilous. The new immigrant became a close ally of Wise as both sought to influence President Roosevelt on issues concerning the Jewish community and to raise American public awareness of the Nazi menace. In these endeavors, Wise’s friendship with Roosevelt was critical, though more radical voices in the Jewish community accused Wise of being too accommodating of the president’s other political and strategic concerns.

Einstein may have disagreed with Wise about the efficacy of a boycott of German goods in 1933, but the two men were in agreement on most issues, especially the need to afford entry into the United States for the ever more desperate refugees fleeing Europe. This took on added urgency in late 1942 when Wise discussed in a press conference a telegram that revealed the Nazi “Final Solution” to exterminate European Jewry. The press conference did not even make front-page news and, in

spite of the revelation, the State Department initiated new measures to exclude refugees. Wise and Einstein were appalled and after lengthy entreaties were able to prevail upon President Roosevelt to create the War Refugee Board in January 1944. However inadequate that contribution was in the face of mass slaughter, the board did relieve the suffering of about 200,000 Jews by the end of the war.

Heinrich Zangger

Zangger (1874–1957) was one of the foremost forensic scientists of his generation and a trusted friend of Einstein. Born into a well-to-do farming family in Bubikon, in the canton of Zurich, he attended the Zurich cantonal school for his secondary-school education. Through exhaustive readings, he gained a thorough knowledge of the natural and human sciences, and developed an encyclopedic interest in the overlapping aspects of medicine, law, politics, and ethics.

Zangger began his university teaching career in 1902 as associate professor of Comparative Anatomy in the Veterinary Medicine Faculty of the University of Zurich. While waiting to secure a position at his own institute and a full professorship in forensic medicine in Zurich, he conducted research at the Institut Pasteur and the Sorbonne in Paris. Finally, in 1912 he received his long-sought professorship and institute directorship at the university. That same year, Zangger almost single-handedly secured Einstein's appointment as full professor at the ETH. At this early stage of his career, Zangger was already well connected to a network of academic and institutional bodies in Switzerland and Europe. In the case of the Einstein appointment, he went over the heads of the ETH faculty and administration to appeal to a close friend who was serving as Swiss Federal president for the year 1912. (Each member of the Swiss Federal Council served as president for a year in rotation.) In doing so, Zangger managed to incur the enmity of many who thought a professor at a cantonal institution (the University of Zurich) should not meddle in the affairs of the ETH, which was a federal institution.

Beyond the personal affinity of the two men, what united Zangger and Einstein intellectually and emotionally above all was, as Einstein put it, their mutual participation in "the community of solitary individuals who are immune to the epidemics of hatred between peoples, and who see in the elimination of war the first principle of moral health" ("Contribution to the Book of Friends of Romain Rolland," August 18, 1925, cited in Schulmann, *Seelenverwandte*, p. 13).

After Einstein left for Berlin, Zangger began his unofficial role as caretaker and guardian of Einstein's family in Zurich, which essentially had been abandoned by its paterfamilias. Zangger fulfilled this role well into the 1930s. During Mileva's debilitating illness in 1916, he served as a foster parent, inviting Einstein's older son, Hans Albert, into his home and looking out for his younger brother, the sickly Eduard, while he recuperated in a number of sanatoria.

The last days of the relationship between Einstein and Zangger were overshadowed by a misunderstanding. After the Second World War, in his last letter to Zangger, Einstein took offense at a statement that his Swiss friend had written at the beginning of the Nazi dictatorship. As the Jewish persecution in Germany began, Zangger had written that it was not falling on the right ones ("trifft ja doch nicht die Richtigen"). Einstein was appalled at Zangger's implication that some Jews might deserve it. Zangger never responded to this letter.

Zangger's illegible handwriting has proved to be a tribulation to successive generations of Einstein's editors at the Einstein Papers Project and was a foible about which Einstein frequently complained. Einstein repeatedly suggested to his friend that he purchase a typewriter, and on one occasion he despaired of making sense of a letter at all: "I see from fragments that your letter must be very interesting, but I cannot decipher it. Do you have a secretary who could send me a transcription?" (see letter to Heinrich Zangger, after December 3, 1931, in Schulmann, *Seelenverwandte*, Doc. 326).

Health

Health Exam

Einstein's Swiss military service book shows the following result of a health examination that deemed him unfit for active military service at the age of twenty-two (March 13, 1901):

Body height, 171.5cm (5ft, 7.6in)

Chest circumference, 87cm (34.8in)

Upper arm, 28cm (11.2in)

Diseases or defects: varicose veins, flat feet, and excessive foot perspiration

*Source: CPAE, Vol. 1, Doc. 91; Einstein Archives 29-156. According to Helen Dukas, Einstein was required to pay a tax until 1940 for not serving in the Swiss military; a record of the yearly entries was kept in his *Dienstbüchlein* (military service book).*

Health Problems

Einstein suffered from a number of chronic health issues throughout his life, all of them presenting before he reached the age of fifty. They were digestive system disorders: liver ailment, stomach ulcer, inflammation of the gall bladder, jaundice, and intestinal pains. His first major illness, brought on by an abdominal ulcer, occurred in 1917 in Berlin before his marriage to Elsa. He moved into an apartment on the top floor of the building that was occupied by Elsa's family, and she nursed him back to health for several months. Five years later, while onboard ship to the Far East, he again suffered from major intestinal issues. Six years after that, in 1928, he collapsed while in Zuz, Switzerland, and was diagnosed by his physician, Janos Plesch, with an inflammation of the heart. The remedy back then was four months of bed rest and a salt-free diet. Because of his recurring stomach problems, Einstein was sometimes advised not to eat meat, which has often led to the assumption that he was a vegetarian. He was also warned not to drink alcohol, a superfluous piece of advice as he was in effect a teetotaler. On his arrival in New York in 1921, when Prohibition was in force and reporters asked him what he thought of it, he replied that it was all the same to him because he never drank. (See also *CPAE*, Vols. 1, 8; Kantha, "An Appraisal of Albert Einstein's Chronic Illness.")

Myths and Misconceptions

Adoption of Ilse and Margot Einstein

See Family, "Family Relationships."

Asperger's Syndrome

The claim that Einstein suffered from this disorder is a far-fetched hypothesis of modern-day psychologists and psychiatrists who have succumbed to myths about Einstein. The misconception that he lacked social empathy and developed slowly educationally have contributed to this false retrospective diagnosis. Einstein had close friendships with many physicians and none of them have mentioned a mental or emotional disorder in their writings or in conversations with others in Einstein's circle, nor does Einstein's own correspondence reflect such a condition. In fact, he seems to have been very well adjusted, if sometimes rude or insensitive—not unlike many individuals. Some of his social behaviors and attitudes may seem unconventional in today's society, but they were not that unusual in his day and within his milieu. He was very sociable—see his *Travel Diaries*, for instance—and was emotionally involved with friends and family, even if he savored solitude, when it was within his reach, to pursue his science.

Furthermore, some have claimed that Einstein's son, Eduard, inherited his mental illness from Einstein, and thus it ran in his family. Einstein's side of the family may have had their issues, but mental illness was not among them. If Eduard's schizophrenia was inherited, it was more likely from his mother's side of the family. Mileva Einstein suffered several bouts of severe depression and her younger sister, Zorka, Eduard's aunt, was, like Eduard, diagnosed as schizophrenic.

Bad Student

Einstein was a very good pupil, receiving high marks in physics and mathematics and high or above average marks in most other subjects. Confusion about his school performance seems to have originated with a change in the grading system while he attended the Aargau Cantonal School in Switzerland. The myth, advanced by some biographers, arose in part because a “1” denoted the best mark in the first semester and became the lowest in the second semester. This led to the false conclusion that Einstein, who had “1”s in physics and mathematics in the first semester and “6”s in those same subjects in the second semester, had initially been a poor pupil. On the leaving examinations, in fact, he received the highest grade average in his graduating class.

Another fact supporting the myth is that he failed to pass his entrance exam to the Swiss Federal Polytechnical School (later, ETH). What is not well known is that he was given special dispensation to take the exam two years early, at age sixteen (letter of Albin Herzog to Gustav Maier, September 25, 1895, *CPAE*, Vol. 1, Doc. 7; Einstein Archives 71-660). He performed well in the mathematical and scientific parts of the exam, but failed the language and historical sections. This is not surprising, as he had attended a German humanistic *Gymnasium* during his first years of secondary school, where the curricular fare consisted of classical languages (no French) and certainly no Swiss history (Maja Winteler-Einstein’s memoir of her brother, February 15, 1924, *CPAE*, Vol. 1, p. lxv). His performance on the entrance examination for the engineering department was good enough that, had he stayed in Zurich rather than go to Aargau, the physics professor would have allowed him to audit his courses in spite of his age (see “Autobiographical Sketch,” in Seelig, *Helle Zeit-Dunkle Zeit*, p. 9).

Communist

Einstein was not a Communist, even though he was brash enough to say that if he were one, he would not be ashamed of it (see letter to Lydia Hewes, July 10, 1950; Einstein Archives 59-984). The label was assigned to him so often that, in a letter to the *Times* of London in September 1933, shortly before leaving Europe for good, he publicly stated his views on communism: that he never favored it before, and did not favor it now (see no. 144 in [appendix C](#)). His harsh condemnation of McCarthyism and the wave of fear it spread through America in the early 1950s led to the charge in some quarters that he was a subversive left-wing radical rather than a political liberal and freethinker who was independent of any political party. Communist sympathies would have gone against the grain of his belief in the importance of the individual over political affiliations based on ideology. On the other hand, in his interview with Raymond Swing (see nos. 178 and 183 in [appendix C](#)), he claimed he could have adjusted to living in Russia if he had been born there.

Could Have Gone Fishing

It is often said that Einstein achieved nothing of note after 1925 and might as well have gone fishing rather than continue his research in physics. This view was first advanced by no less eminent a figure than Abraham Pais, Einstein’s best-known biographer. It is true that Einstein’s most important contributions to physics had been made by this year, and that his main research program after that time, the unified field theory, did not lead to many productive insights. Nevertheless, there is a certain element of snobbery in Pais’s remark, since Einstein did make a number of significant contributions to general relativity as late as the 1930s, including the first paper discussing gravitational lensing, a well-known paper on gravitational waves, an important paper on the problem of motion, and his paper on wormholes. His assistants went on to form some of the most important research groups of the postwar era. Even after 1925, he still had what would normally be considered a respectable career for a physicist, though it is certainly true that he never reached the heights of his earlier achievements.

Responsible for the Atom Bomb

Einstein's theories may have led to the eventual development of the atom bomb, but in 1905, there was no way he could have foreseen the actual event. In 1939, when he learned that a nuclear chain reaction could be caused by the process of nuclear fission, he exclaimed that such an application had not occurred to him (see Nathan and Norden, *Einstein on Peace*, pp. 291–292). After the discovery in late 1938 of nuclear fission using heavy elements such as uranium, he signed a letter to President Franklin D. Roosevelt in August 1939, as is well known. In the letter, he recommended supporting and speeding up experimental work on developing a nuclear device in order to keep abreast of possible advances in this area by a hostile Germany. (See the letter to Roosevelt in [Part III](#), Political Contexts, “Hitler in Power and the Second World War—Letters to FDR.”) Even though he identified strongly with the U.S. war effort, he had no security clearance and the FBI still considered him “subversive.” He therefore was not privy to what went on in the Manhattan Project, the huge enterprise that built the bombs, nor could he have foreseen or influenced the decision to use such bombs against Japan ([fig. 28](#)). In his words, as he stated in a letter to the editor of the Japanese general-interest magazine *Kaizō* on September 20, 1952: “My participation in the construction of the atomic bomb consisted of one single act: I signed a letter to President Roosevelt in which I emphasized the necessity of conducting large-scale experimentation with regard to the feasibility of producing an atom bomb. I was well aware of the dreadful danger which would threaten mankind were the experiments to prove successful. Yet I felt compelled to take the step because it seemed probable that the Germans might be working on the same problem with every prospect of success.” In an effort to do his part in the war, however, in 1943 he accepted the U.S. Navy's invitation to be a consultant on high explosives. After the war, he became active in calling for disarmament and banning nuclear and other weapons by all nations, a conviction that meshed with his earlier pacifist inclinations.

Left-Handedness

Because of the belief that many physicists and mathematicians are left-handed, some people think the preference for that hand is a sign of genius—no doubt a myth in itself. Genius or not, however, Einstein was right-handed. He wrote with his right hand and held his violin bow in his right hand. Though most violinists are taught to hold the bow in their right hand so that all players in an ensemble move their bows on the same side, Einstein played that way naturally. He also pointed with his right hand, as seen in various photographs of him. Most conclusively, there are several photographs of him standing by a blackboard holding the chalk in his right hand, including one in which he appears to be in the act of writing.



FIGURE 28. Photo of the Hiroshima bomb explosion. In a letter written on January 23, 1950, Einstein maintained he had “never done research having any bearing on the production of the atomic bomb.... In 1905 I established the relationship between mass and energy, a truth about the physical world of a very general nature, where possible connection to the military potential was completely foreign to my thoughts.” (AP photo, from a photo taken in Kure, Japan. New York World-Telegram and the Sun Newspaper Collection, Library of Congress)

Mileva Marić as Alleged Collaborator

In March 27, 1901, while Einstein was engrossed in seeking a job and having difficulty finding one, he wrote to his girlfriend, Mileva Marić:

You are and remain to me a sanctuary that no man can enter; I also know that you love and understand me better than anyone else. I can also assure you that no one here will dare or want to say anything bad about you. How happy and proud I will be when the two of us together will have brought our

work on relative motion to a triumphant end! (CPAE, Vol. 1, Doc. 94)

The last sentence implies that Einstein and Mileva had been working on “relative motion” together, and the statement caused considerable controversy when it was revealed in the early 1990s. It raised the possibility that Mileva might deserve a share of the credit for the eventual breakthrough that led to Einstein’s publication on relativity during his *annus mirabilis* (see [Part II](#)) four years later. We must note, however, that “relative motion” did not mean “special theory of relativity” when he wrote the letter in 1901, and Einstein did not produce a final formulation of the theory until 1905 (see Martínez, *Science Secrets*).

Mileva’s Serbian biographer, Desanka Trbuhović-Gjurić, in her book, *In the Shadow of Albert Einstein* (1960), was convinced that the couple worked together on relativity in a significant way. Joining her in this opinion later were Serbian physicist Đorđ Krstić and American physician Evan Walker. On the other side—at least a quarter century after the publication of Trbuhović’s book and after the discovery of the Einstein-Marić love letters—were the Einstein scholars, most notably physicist John Stachel, the founding editor of *The Collected Papers of Albert Einstein*; Allen Esterson (see [esterson.org](#)), and Alberto Martínez, a historian of physics and mathematics at the University of Texas. A judicious reading of the claims made by Trbuhović-Gjurić, Krstić, and Walker reveal their sensationalist character and their flimsy and questionable handling of evidence. Mileva herself never claimed to be a partner in relativity theory, as a recent collection of her letters to a friend shows. (See Popović, ed., *In Albert’s Shadow*.) Einstein scholars do not deny that Mileva was intelligent in her own right and probably, as a fellow physics student, played a role as Einstein’s helper, listened to his ideas, and likely proofread his papers carefully—thus including her in his remarks about “our paper.” To date, however, there is no documented evidence that she was a creative force behind his work. (See also Alberto A. Martínez, “Handling Evidence in History.”)

Only Ten or Twelve People Can Understand Relativity Theory

In their coverage of the vindication of relativity theory by the 1919 eclipse expedition (see [Part II](#), Relativity Theory, “General Relativity—Experimental Tests of General Relativity”), the press seized upon the idea that only a handful of brilliant individuals could comprehend the theory. This notion circulated widely, with a precise number of such people often being noted, for instance, three, nine, ten, or twelve. One can even find anecdotes declaring that famous people were unable to publish a book because they allegedly discussed relativity in it, and the publishers refused to accept the manuscript on the grounds that the author was not on the short list (apparently recorded somewhere) of those who understood the theory.

The belief that Einstein’s theory of general relativity is particularly abstruse has persisted to this day. This belief is founded on truth, given that many scientific contemporaries complained that the theory was too difficult. Even today, few physics students take a class in the subject until graduate school. Early on, Einstein himself may have contributed to the myth by writing to his friend Heinrich Zangger the following in the immediate aftermath of his final publication of the theory: “The theory is beautiful beyond comparison. However, only one colleague has really been able to understand it” (November 26, 1915; CPAE, Vol. 8, Doc. 152). The colleague in question was the mathematician David Hilbert (see [Part II](#), Colleagues), and it is true that a training in mathematics (or mathematical physics) is the best preparation for studying general relativity.

Other theorists were not above playing up to this myth. The celebrated astrophysicist Subrahmanyan Chandrasekhar recalls that Arthur Stanley Eddington (see [Part II](#), Colleagues) once related the following anecdote: “After the discussion [at the Royal Society] [Ludwik] Silberstein came up to me and said, ‘Well! Professor Eddington, you must be one of the three people in the world who understands relativity.’ I said, ‘Oh, I don’t know ...,’ to which Silberstein said, ‘Professor Eddington, don’t be modest.’ To which I replied, ‘On the contrary! I am wondering who the third person is!’” (cited in Wali, *Chandra*, p. 31).

The problem with this myth is that it exaggerates the difficulty of the theory. While Einstein could observe, in 1915, that only one colleague had yet understood the theory, by 1920, when the myth was emerging, certainly several dozen scientists

understood it quite well, and the numbers have obviously only continued to increase since then. Even Eddington's remark was clearly intended both to lampoon the misconception that only a handful of individuals had the capacity to understand the theory as well as to prick the pomposity of Silberstein (see [Part II](#), Rivals), who probably imagined himself to be the third man in the equation.

Einstein viewed this myth with impatience soon after it emerged: "Everywhere I go, someone asks me that question. It is absurd. Anyone who has had sufficient training in science can readily understand the theory. There is nothing amazing or mysterious about it. It is very simple to minds trained along that line, and there are many such in the United States" (from an interview with the *Chicago Daily Tribune*, published May 3, 1921, sec. 1, 3, in response to the question if it is true that only twelve men can understand his theories of relativity; see also Illy, *Albert Meets America*, p. 147).

While it is true that general relativity requires years of study in order to become proficient in it, many people have undertaken this task, and many more can grasp the essentials of the theory without benefit of long and onerous study.

Political Naiveté

Einstein had little use for conventional political organizations. Preferring to remain outside the arena of professional politics, he lent his name to numerous causes, but never joined a political party nor felt himself accountable to any constituency. Fiercely independent, he was willing to take unpopular stands that sometimes left even his allies disgruntled or bewildered. These traits have contributed to the stubbornly persistent misconception that Einstein was simply a naive idealist who pontificated to no real purpose, an isolated genius cut off from the realities of contemporary political events. *Time* magazine, while elevating him to "Person of the Century," only reinforced this stereotype of Einstein as "the embodiment of pure intellect, the bumbling professor with the German accent, a comic cliché in a thousand films." Even when he "denounced McCarthyism and pleaded for an end to bigotry and racism," his American admirers regarded him as "well meaning if naive" (*Time*, January 3, 2000) while his detractors thought him outright dangerous.

When idealistic views remain unchecked by a realistic assessment of the everyday world, these views may rightly be called naive. But this charge does not apply to an Einstein who radically altered his position on pacifism, expressed his sorrow at the trajectory of Zionist goals in Palestine, and despaired of the military mentality and the arms race to which it led. The same pragmatism that marked the early stages of his personal and professional lives came to shape his political views, which he constantly adapted and adjusted to changing circumstances while never abandoning principle. In rebutting a critic of his views on world government shortly after the end of the Second World War, he stressed that one's strength of conviction must be "based upon clear understanding of the prevailing objective conditions" ("Reply to Sumner Welles," ca. January 1946; Einstein Archives 28-720). His humane and democratic instincts were always tempered by a willingness to evaluate ideas in the light of their consequences in everyday life.

Source: Modified from Rowe and Schulmann, *Einstein on Politics*, pp. xxii–xxiii.

Vegetarian

Einstein was not a vegetarian by choice, though he became sympathetic to the practice. His doctors often instructed him to avoid meat because of his digestive problems, which may have led to the mistaken label of vegetarian. Still, he wrote one person that he always felt guilty when eating meat, and in December 1930, he wrote a letter published in a German vegetarian periodical: "Although I have been prevented by outward circumstances from observing a strictly vegetarian diet, I have long been an adherent to the cause in principle. Besides agreeing with the aims of vegetarianism for aesthetic and moral reasons, it is my view that a vegetarian manner of living by its purely physical effect on the human temperament would most beneficially influence the lot of mankind" (letter to Hermann Huth, December 27, 1930; Einstein Archives 46-756). On September 2, 1923, Einstein wrote to Elsa while vacationing with Hans Albert, that his son, "like me," eats almost no meat but huge

amounts of vegetables.

Verification of General Relativity Theory Was Unimportant to Einstein

There is a story that Einstein reacted nonchalantly to the celebrated vindication of his theory by the 1919 eclipse expedition (see [Part II](#), Relativity Theory, “General Relativity—Experimental Tests of General Relativity”). A young student visited him shortly after the arrival of the telegram informing him of the expedition’s success. When asked by the student, Ilse Rosenthal-Schneider, how he would have reacted if the theory had not been confirmed, he replied: “I would have had to pity our dear God. The theory is correct all the same” (cited in Ilse Rosenthal-Schneider, *Reality and Scientific Truth*, p. 74).

This attitude of cocksure confidence concerning his theoretical predictions was an Einstein quality that struck his contemporaries profoundly, and has become a common stereotype about theoretical physicists in the years since. Einstein’s confidence in himself and his ideas should not lead to the impression that he did not care about experimental verification. He devoted enormous effort to encouraging astronomers to test his theory, even personally raising funds to finance eclipse expeditions with that aim in mind. In the early days, he had sought experimental tests as a way to guide him in his quest for the theory. When these tests did not materialize, he forged his path with ingenious thought experiments and burdensome calculations. By the time the tests were completed, he had such faith in the theory—after years of work—that his belief in it was not easily shaken. Even then, he felt it was important that further tests be undertaken if any doubt remained. If attempts at verification yielded a result other than the one he expected, he accepted the new result as a guide toward a new and better theory. (See *CPAE*, Vol. 9, pp. xxxi–xlii, for a thorough discussion of the path to the confirmation of general relativity; see also Crelinsten, *Einstein’s Jury*.)

The real source of Einstein’s confidence in the face of adverse experimental results was his ability to deduce conclusions on the basis of previous experiments that were not immediately obvious even to fellow physicists. Thus, by 1919, when he spoke with Rosenthal-Schneider, he had deduced that light has energy and, therefore, mass, and so it must fall into a gravitational field (explaining part of the observed effect from the eclipse); he also concluded on the basis of the equivalence principle and as confirmed by the Mercury perihelion advance (see [Part II](#), Relativity Theory, “General Relativity—Experimental Tests of General Relativity”) that spacetime must be curved. A result that contradicted his prediction would have indirectly implied that certain well-established previous experimental results were incorrect. In such a circumstance, Einstein would have felt confident in calling for a second test of the eclipse prediction to check for the possibility of an error in the first measurement.

Was Only a Theorist

A common misconception about Einstein is that he worked exclusively in theoretical physics. In fact, he enjoyed doing experiments and was an accomplished inventor and tinkerer who held many patents (see the section on his collaborators, such as Wander de Haas, for some discussion of his experimental work, including his patent work; see also [Part II](#), Patents and Inventions, and Scientific Sidelights).

It is true that Einstein was among the first generation of theorists who concentrated professionally on their theoretical work and for whom experimental work was an option. Before Einstein’s time, positions in theoretical physics were fairly rare in universities, though some professional mathematicians did a good deal of work in what we would now describe as theoretical physics. However, the suggestion that he never undertook experimental work is a misconception, no doubt inspired by the belief that theorists are profoundly impractical people who can ruin an experiment simply by walking into the laboratory. The theorist who did the most to popularize this impression was Einstein’s colleague Wolfgang Pauli. The “Pauli effect” was famous among mid-twentieth-century physicists, and referred to Pauli’s uncanny ability to interfere with the proper running of experiments, allegedly by his mere presence in the vicinity.

Pastimes

Hiking

For relaxation, especially in his younger years, Einstein enjoyed taking to the mountains. As a pupil at the Aargau Cantonal School in 1896, he and his classmates climbed the Säntis massif in eastern Switzerland on a geology field trip. During his days as a patent clerk, he made excursions to the Gurten, a sprawling mountain south of Bern, with his friend Maurice Solovine. They would start out very early in the morning while the stars were still twinkling, and reach the summit at dawn, in time to watch the sunrise during the summers. Solovine wrote that the experience often led to discussions on astronomy. On a number of occasions, they also hiked some 18 miles from Bern to the Beatenberg overlooking the Lake of Thun, a walk that took six hours and spurred conversations on the geology of the Alps. In the evening, they returned by train. With Mileva, he went to Lake Como in northern Italy and over the Splügen Pass into Switzerland, a trip on which she became pregnant with daughter “Lieserl.” Perhaps most famously, Einstein hiked over the Maloja Pass in the Engadine with Marie Curie ([fig. 29](#)) and her daughters in summer 1913. During the First World War, he took a walking tour with Hans Albert on the Seelisberg overlooking the Lake of Lucerne. Throughout his life, he enjoyed walking in the outdoors and continued to do so in old age with mathematician Kurt Gödel while in residence at the Institute for Advanced Study.

Music

Music played a large part both in Einstein’s emotional life and in his social life. He began violin lessons at age six. He was so attached to his instrument in adulthood that he named it, “Lina,” and it accompanied him on most of his travels ([fig. 30](#)). He also played the piano, especially in his later years, because, he claimed, it was less strenuous than violin playing, which he gave up by age seventy: “I am done fiddling. With the passage of years, it has become more and more unbearable to me to listen to my own playing,” he wrote to his friend Elisabeth, Queen of the Belgians, on January 6, 1951 (Einstein Archives 32-400). (*See also* his verse to that effect in “Writing Poems and Aphorisms,” *below*.) His musical preferences were the European classics, especially the music of Bach and Mozart; he considered Beethoven too temperamental. Schubert, Schumann, and Brahms, as well as some old Italian and English masters, were also among the composers whose music he played with other amateur musicians. (*See* the response to a questionnaire, undated; Einstein Archives 34-322.)



FIGURE 29. Einstein with Marie Curie, on a hiking trip in the Engadine Valley of the Swiss Alps, 1913. (Wikimedia Commons)



FIGURE 30. Einstein playing his violin, 1944. (Courtesy of the Leo Baeck Institute)

Einstein took some interest in Eastern music as well, as demonstrated in one of the three conversations he held with Rabindranath Tagore, the wealthy but progressive Bengali poet, philosopher, artist, musician, and Nobel Prize laureate in literature (1913), whom he nicknamed “Rabbi Tagore.” European intellectuals of the time were curious about Eastern arts and philosophy, and Tagore became their Einstein of that

genre. The conversation that included the differences in Western and Eastern music took place on August 19, 1930, in Berlin, at the home of mutual friends Toni Mendel and her daughter Hertha and son-in-law Bruno. Though the conversation is interesting to read, Einstein claimed that the transcription, undertaken by his son-in-law Dmitri Marianoff, was not completely faithful to the actual conversation. (See Rabindranath Tagore, *Das Goldene Boot* [The Golden Boat], ed. Martin Kämpchen [Düsseldorf and Zurich, 2005], for the transcript.)

During his travels to the Far East, Einstein encountered Japanese music firsthand and left behind these thoughts, though he never claimed to truly understand or enjoy the music:

The differences between Japanese music and our own are truly fundamental. Whereas in our European music, chords and architectural arrangement are essential and are a given, they are absent in Japanese music.... To me, Japanese music is a painting of emotions that has a surprising and immediate effect.... I have the impression that it is all about giving a stylized presentation of the emotions found in the human voice, as well as the sounds of nature that stir the human soul, such as birdsong and the rumble of the ocean.... To my mind, the greatest obstacle to the acceptance of Japanese music as a great art form is its lack of formal arrangement and architectural structure. (Musings on My Impressions in Japan; Einstein Archives 36-477.1. Also published in *Kaizō* 5 (1923): 338–343.)

Finally, in recognizing the contributions of blacks to American music, he declared at the dedication of the Wall of Fame at the New York World's Fair in 1939: "To the Negro and his wonderful songs and choirs we are indebted for the finest contribution in the realm of art which America has so far given the world" (Einstein Archives 28-527).

Reading

Judging from the books he mentioned and recommended in various pieces of his correspondence, Einstein was an ardent reader. No systematic compilation of these books has been completed and published yet, but Herodotus, Spinoza, Dostoevsky, Tolstoy, and Anatole France rank high among the non-science books. At age thirteen, he read Kant's *Critique of Pure Reason* and, while a student, Schopenhauer's aphorisms on worldly wisdom. Like other intellectuals of his time, he read the classics in addition to books that were currently popular or important and piqued his interest, in addition to the many books that kept him up-to-date and influenced him in his studies and professional life. When taking sea voyages, Einstein would bring along boxes of books on a number of topics to help pass the time.

See also Einstein's letter to Maurice Solovine, April 24, 1920; Einstein Archives 21-114; and [Part III](#), Organizational Ties, "Olympia Academy," which contains that group's reading list. Outdated but perhaps of interest to some is Einstein's "Atomic Science Reading List," no. 189 in [appendix C](#). On his belief that young people should read the classics, see no. 198 in [appendix C](#). Regarding his reading of Dostoevsky's *The Brothers Karamazov*—"the most wonderful book that has ever fallen into my hands"—in spring 1920, see his letters to Heinrich Zangger, March 26, and Paul Ehrenfest, April 7, CPAE, Vol. 9, Docs. 361 and 371.

Sailing

Besides playing the violin and piano and listening to classical music, Einstein's other leisure-time passion was sailing. For his fiftieth birthday in 1929, friends surprised him with a generous gift: his own sailboat. It was perfect for sailing on the Havel River at his summer home in Caputh, southwest of Berlin. The boat, a 215-square-foot dinghy paneled in mahogany, was called *Tümmler* ("porpoise"; [fig. 31](#)). The shipbuilding engineer and designer Adolf Harms was given the task of building a sailboat with an auxiliary engine and a small deck—a boat that would be easy to operate. When he moved to Princeton, Einstein sailed on Lake Carnegie in his more modest boat, *Tinnef* ("cheaply made" in Yiddish). Einstein could not swim, yet he was fearless of water or capsizing. Once, when he fell overboard in shallow water, he is

said to have held on to his pipe—smoking a pipe was another pleasure—even as he struggled to get back onboard. Some of the best-known photographs of Einstein were taken on his sailboat by photographer Lotte Jacobi, who bequeathed the lot to the University of New Hampshire.

Writing Poems and Aphorisms

The Einstein Archives are replete with hundreds of poems, short verses, limericks, and aphorisms. None of Einstein's verses fall into the genre of serious poetry. All of them are written in German, and, as is well known, it is difficult to translate poems from one language into another, particularly when they are infused with humor—much of it tongue-in-cheek—and idioms. The following translations come from a variety of published sources and include the translator's name when known. Though some of these English versions may sound inelegant, in reading them readers can get a sense of the extent—and sometimes the limitations—of Einstein's poetic abilities. His poems were often written on postcards or photographs, and mostly to women. Most of them are not passionate cries from the heart but were intended to amuse the recipient, and were generally left untitled. The rhythm and rhyme of most of the poems are similar to those of the German humorist and poet Wilhelm Busch of "Max und Moritz" fame. (Poems and aphorisms reprinted courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel.)

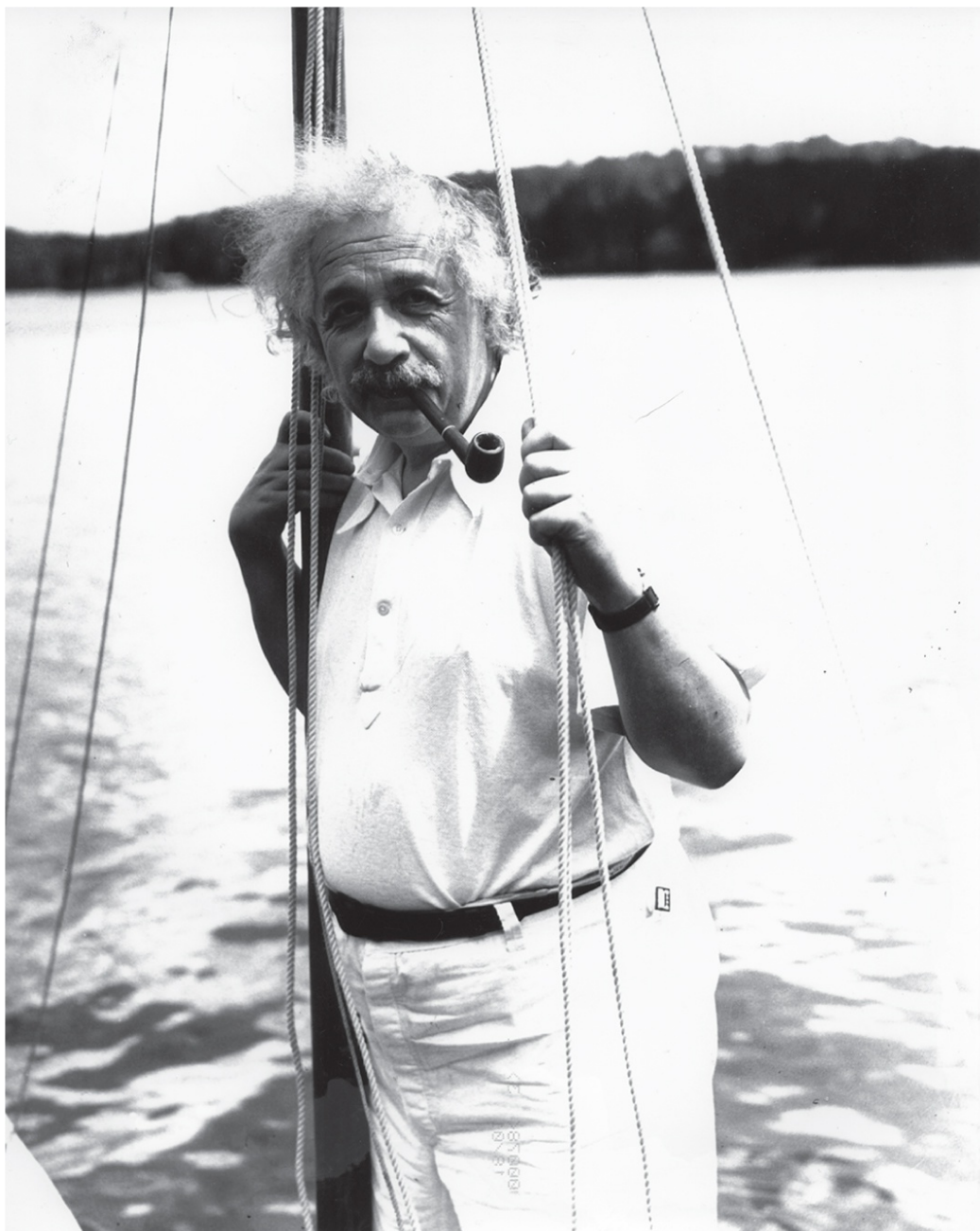


FIGURE 31. Einstein sailing his sailboat *Tümmmler* near his summer home in Caputh outside of Berlin. (© 1937 Lotte Jacobi Collection, The University of New Hampshire; courtesy of The University of New Hampshire)

POEMS

Wherever I go and wherever I stay
There's always a picture of me on display.
On top of the desk, or out in the hall,
Tied round a neck, or hung on the wall.
Women and men, they play a strange game,
Asking, beseeching: "Please sign your name."
From the erudite fellow they brook not a quibble
But firmly insist on a piece of his scribble.
Sometimes, surrounded by all this good cheer,
I'm puzzled by some of the things that I hear,

And wonder, my mind for a moment not hazy,
If I, and not they, could really be crazy.

*Dedicated to Cornelia Wolff, January 1920. In Dukas and Hoffmann,
Einstein, the Human Side, pp. 73-74*

How much I love that noble man!
More than I can tell with words.
I fear, however, he'll stand alone
With a halo all his own.

On the Jewish philosopher Baruch Spinoza, 1920. Einstein Archives 33-264

Men and women of all ages
Leave your mark upon these pages.
But not with prose resembling that
Of people as they stop to chat;
Arrange your words in flowing lines
Like lofty poets' neat designs.
Begin, and push your fears away
Your writing will not go astray.

*Preface to the guestbook at the house in Caputh, May 4, 1930. Trans. Aaron Wiener
in Neffe, Einstein, p. 306. Einstein Archives 31-067*

Long-branched and delicately strung,
Nothing will escape her gaze.
The welcome sight of her friends
Smiling, and still a weeping willow.

To Ethel Michanowsky, May 16, 1931. Einstein Archives 84-103

Whoever has let a daughter of Eve
Into his black heart
Feels sorry for the day that flies by quietly
When he can't catch a glimpse of her.

To Ethel Michanowsky, 1932 or 1933. Einstein Archives 84-108

A thousand letters in the mail,
And every tabloid tells his tale.
What should he do instead of brood?
He sits and hopes for solitude.

1934. Einstein Archives 31-161

In the Capital's proud glory
Where Destiny unfolds her story,
Fights a man with happy pride
Who solution can provide.
Of our talk of yester night

There are cordial mem'ries bright,
In remembrance of our meeting
Let me send you this rhymed greeting.

Written for Elisabeth, Queen of the Belgians, during the Einsteins' visit to FDR's White House, January 25, 1934, after they had spoken fondly about the queen. The poem was given to FDR and translated by the Department of State's Translating Bureau. The White House returned the original to Einstein for posting to the queen.

All my friends are hoaxing me
Help me stop the family!
Reality's enough for me,
I've borne it long and faithfully.
And yet it would be nice to find
That I'd possessed the strength of mind
To lay eggs on the side—so long
As others didn't take it wrong.
A. Einstein, Stepfather

1936, to friend János Plesch, responding to rumors that he had fathered an illegitimate child. Translation in Highfield and Carter, Private Lives, pp. 93–94. Einstein Archives 31-178

Even if one loves to play
One's little fiddle every day,
It's not right to broadcast it,
Lest the list'ners scoff at it.
If you scratch with all your might—
Which is certainly your right—
Then bring down the windowpane
So the neighbors don't complain.

To Emil Hilb, April 18, 1939. Trans. Alice Calaprice. Einstein Archives 31-279

Through sweat and effort beyond compare
To arrive at a small grain of truth?
A fool is he who toils to find
What we call the Party line.
And those who dare to express some doubt
Will quickly find their skulls bashed in.
And thus we educate as never before
Bold spirits to embrace harmony.

"The Wisdom of Dialectical Materialism," 1952. On the same page, Einstein scrawled a sarcastic aphorism, "Inscription for the Marx-Engels Institute: In the realm of truth-seekers there is no human authority. He who attempts to play the ruler there will run afoul of the laughter of the gods"; see Rowe and Schulmann, Einstein on Politics, p. 457; Einstein Archives 28-948. The final sentence of this aphorism was included in Essays Presented to Leo Baeck on the Occasion of His Eightieth Birthday (London: East and West Library, 1954), p. 26. Einstein Archives 28-962

Whoever writes grim fairy tales
Will end up in our harshest jails.
But if he dares the truth to tell
We'll cast his soul down into hell.

Quoted by Peter Bucky in Neffe, Einstein, p. 285

The Jews around me that I see
Little pleasure give to me.
When the others I then view,
I am glad to be a Jew.

Trans. Josef Eisinger. Einstein Archives 31-324

APHORISMS

Germany had the misfortune of becoming poisoned, first by abundance, and then by privation.

1923. Einstein Archives 36-591

To punish me for my contempt of authority, Fate has made me an authority myself.

For a friend, September 18, 1930. Einstein Archives 36-598

Politics is an oscillation between anarchy and tyranny that is animated by perpetually rejuvenated illusions.

1937. Einstein Archives 28-388

I never think of the future. It comes soon enough.

1945-46. Einstein Archives 36-570

A Meaningful Life: Personal existence gains meaning through conviction of the objective value of one's own ambition and accomplishment. But if this conviction is not softened by humor, one becomes insufferable.

To Johanna Fantova, October 9, 1948. One of three aphorisms sent to her on that day. Einstein Archives 87-347

Compromise: The path of rotten compromises is a "one way road." There is no U-turn and no stopping.

To Johanna Fantova, October 9, 1948. In the original German aphorism, Einstein wrote "one way road" in English. Einstein Archives 87-347

The Individual and the State: It is not possible to imagine a forest made up only of vines. It needs trees that are able to stand by virtue of their own strength.

To Johanna Fantova, October 9, 1948. Einstein Archives 87-347

A life directed chiefly toward the fulfillment of personal desires will sooner or later always lead to bitter disappointment.

To T. Lee, January 16, 1954. Einstein Archives 60-235

The attempt to combine wisdom and power has only rarely been successful, and then only for a short while.

In Essays Presented to Leo Baeck on the Occasion of His Eightieth Birthday (London: East and West Library, 1954), p. 26. Einstein Archives 28-962

Few people are capable of expressing with equanimity opinions that differ from the prejudices of their social environment. Most people are even incapable of forming such opinions.

Ibid.

Romantic Interests: Actual, Probable, and Possible

Much has been made of the fact that Einstein loved the company of women. Though we have information about some of them, we do not know if all the relationships were intimate. His biographies provide little about them, beyond assertions that some women were his mistresses.

Aside from his innocent relationship with Marie Winteler while he was a teenager in Switzerland, Einstein had another short-term crush before his first marriage to Mileva Marić. Anna Schmid, the sister-in-law of a hotelier in Mettmenstetten near Zurich, where Einstein summered with his mother during his years at the ETH, was the recipient of some of his early flirtatious poems. After marriage, Mileva accused Anna of continuing to maintain a correspondence with Einstein.

Einstein's only known intimate transgression during his marriage to Mileva Marić was with Elsa Löwenthal, who would become his second wife. During this extramarital courtship, he was also romantically interested in Elsa's daughter Ilse and flirted with Elsa's younger sister, Paula. While married to Elsa, when he was in his mid-forties, he regularly showed interest in women with a variety of backgrounds, some married and some widowed or unmarried. He had four "interests" in Berlin and at his summer home in nearby Caputh: Estella Katzenellenbogen, Margarete Lebach, Ethel Michanowsky, and Toni Mendel. The relationship with Lebach might have continued later in the United States, since there are photographs of the two sailing together in Huntington, Long Island, in 1937. He met another woman, Else Jerusalem, onboard ship on his way to Argentina in 1925 (*see* *Travels and Travel Diaries*); he sought out her company, but it is unlikely that a deeper relationship developed during this relatively short period. Some women, such as Toni Mendel, might only have been intellectual intimates and close friends.

Elsa was well aware of these women, some of whom tried to befriend her and showered her with delicacies when they visited. She became especially jealous of Margarete Lebach. When Elsa's daughters, Ilse and Margot, saw how pained she was by her husband's indiscretions, they advised her to make a choice: either end the marriage or put up with her husband's dalliances. Preferring marriage to Einstein and the life it offered her over her other options, she resigned herself to the alienation of his passion for her, if not his affection. Einstein did not seem to consider Elsa a burden, as he had Mileva, no doubt because she was more accommodating.

Einstein's marriage to Elsa lasted for seventeen years, until her death in Princeton in late 1936, after which Einstein became a widower for almost two decades. During the last ten years of his life, two women from Eastern Europe, first Margarita Konenkova and then Johanna Fantova, were often at his side. There have been rumors about others as well, such as Evelyn Einstein's mother, who is said to have been a dancer in New York City (*see* *Family*, Family No. 1—Evelyn Einstein). Throughout his adult life, Einstein questioned the necessity of matrimony, maintaining that "marriage is the unsuccessful attempt to make something lasting out of an incident" (quoted by Otto Nathan in 1982 for Jamie Sayen's book, *Einstein in America*).

The following is a compilation of short biographies researched from various available sources—including genealogy websites—about the women known to have played a part in Einstein's life, presented in the order he met them. Some of these women were accomplished, resourceful, and entrepreneurial. All led interesting and tumultuous lives during a challenging historical era. Einstein's two wives, Mileva and Elsa, are not included here; their biographies can be found in the Family section.

Marie Winteler (1877–1957)

(*See also* Friends, "Winteler Family.")

Young Marie (not to be confused with Einstein's sister Maria, or Maja, Einstein, who married Marie's brother Paul and became known as Maja Winteler-Einstein) was Einstein's first love. She was born in the Swiss canton of Bern and met Einstein in 1896 when she was nineteen and he was seventeen and a pupil at the Aargau Cantonal School in Aarau, Switzerland, and boarded with the Winteler family (*see below*). Both sets of parents approved of the budding romance, which lasted only about a year. Einstein broke off the relationship after he moved to Zurich to attend the Swiss Federal Polytechnical School (ETH). This breakup caused him some guilt and anguish, as he admitted in a letter of May 1897 to Pauline Winteler, her mother, with whom he had a warm relationship. Later in life, Marie claimed that their friendship was only platonic but their love was real. She married Albert Müller in 1911, had two children, and was divorced in 1927. She battled mental illness as an adult and died in 1957 at the psychiatric clinic in Meiringen near Bern at age eighty.

Ilse Einstein (1897–1934)

See Family, "Family No. 2."

Betty Neumann (1900–1975?)

Betty Neumann was the foster daughter and distant relative of Einstein's close friend, Hans Mühsam. Einstein hired her in June 1923 to assist him temporarily when his secretary and stepdaughter Ilse Einstein became ill with severe colic and while Betty, who lived in Vienna, was visiting the Mühsams in Berlin. According to a letter of recommendation for her written by Einstein in August, the employment lasted only six weeks (CPAE, Vol. 14, Doc. 103; Einstein Archives 90-782).

Einstein, however, was so infatuated with the intelligent young Betty that he continued to carry on a romantic correspondence with her, at first secretly and then with Elsa's knowledge. Elsa endured the affair, leaving the apartment when her husband and Betty would meet there twice a week for a rendezvous. Furthermore, as he wrote to Betty in November 1923, Einstein claimed to have turned down a position from Columbia University in New York because she declined to accompany him as his secretary: "Why should one go to sea without any wind in one's sails and no coal for the steam boiler?" (November 13, 1923; Einstein Archives 120-896). He often professed his love for her even while encouraging her to find a husband closer to her own age. Apparently she tried to heed his advice, and was either married or engaged in late 1923, though the groom was even older than Einstein. By January 1924, Einstein already made reference to her short-lived liaison and "divorce," and the two paramours continued to write love letters to each other.

Toward the end of 1924, when Betty was twenty-five and Einstein was forty-five, he finally admitted in a letter to her that the relationship was wrong, that he wanted to end it so she could get on with her young life. From now on, he advised her, she should think of him as her kindly uncle. He famously told her in the same letter that he was an old fellow and needed to "seek in the stars that which is denied to me on Earth" (October 28, 1924; Einstein Archives 120-911). This communication seems to have ended the correspondence. This unexpected closure apparently hurt Betty so much that Hans and Minna Mühsam, who had been close to Einstein, ended their friendship with him. It was slowly reestablished many years later, when the old friends lived on different continents.

The Einstein Archives contain evidence that Einstein had given Betty a signed, six-page manuscript of one of his papers, "Non-Euclidean Geometry and Physics," handwritten in German and dated March 1924, which she sold forty years later for \$2,150 (receipt in Einstein Archives 90-792). (He made a similar gift to Johanna Fantova many decades later.) According to a manuscript she wrote about her tenure as Einstein's secretary (*see below*), she also asked for and received a lock of his hair for her secretarial services in lieu of money, which she said she didn't need.

In 1938, the correspondence suddenly resumed, but the tone was different. Perusal through the Einstein Archives database shows that erratic further correspondence took place from May 1938 to March 1955. By 1938, Einstein and his family had immigrated to the United States, and Betty, unmarried at age thirty-nine and very frightened, found herself alone in Vienna during the Nazi annexation of Austria. In desperation, she wrote to Einstein in May 1938, informing him that she had been

fired from her job as an X-ray technician in a hospital, that she had no parents to turn to and had no means of support except herself, and would he be able to get an affidavit from the American consul in Vienna for her, to help with the immigration process?

By the end of the year, Einstein had arranged for the requested affidavit, including the guarantee that she would have a place to live and money to support herself. The details of her emigration from Vienna are not extant, but by March 1939, she had found her way to Haifa, probably to visit the Mühsams, who had fled to Palestine. She must have arrived in New York City by May, as a letter reveals that Einstein agreed to meet with her at the home of his friend Gustav Bucky that month (May 22, 1939; Einstein Archives 120-915). In early June, Einstein wrote a letter of recommendation for employment for her. By July 1940, she had found a full-time job in a hospital as an X-ray technician and had begun occasionally spelling her name “Newman.”

Not much personal contact seems to have taken place between Betty and Einstein after her arrival in New York. They exchanged some friendly letters in which they made remarks about hoping to meet soon, but there is no indication they actually met. The two were by now addressing each other again with the formal German “Sie” rather than “Du,” and the exchanges reveal no clues about their earlier love affair.

Einstein’s last letter to Betty was on March 6, 1955, six weeks before his death. She wanted to visit him, she wrote, but he replied that he was too ill and too old for a meeting (Einstein Archives 120-931). She rushed to Princeton when news of his death reached her, but apparently no one in the family could see her. In an apologetic letter, Helen Dukas later wrote her that the commotion was too great that day for them to be able to accommodate anyone but family and their closest friends.

In 1956, a typescript in English, written by Betty and titled “When I Was Einstein’s Secretary,” made its way into the Einstein Archives. It may be the same manuscript she had wanted to publish in 1941. At that time, Einstein wouldn’t allow its publication because he felt it was an embarrassing piece of writing (March 13, 1941; Einstein Archives 120-925). In it, she refers to some of their excursions around Berlin, but not in the context of any romance. After the 1964 sale of the handwritten manuscript Einstein had given to her, mentioned above, we could find no further record of the rest of Betty Neumann’s life, except for a postcard written to a friend in New York from Switzerland in August 1967.

Else Kotányi Jerusalem (1877–1942?)

Einstein met Else Kotányi Jerusalem, to whom he referred as the “Panther Cat” in his travel diary, during an ocean voyage to South America in spring 1925 aboard the luxury liner *Cap Polonio*, a trip that Elsa Einstein skipped. He also saw her during his time in Buenos Aires. (See *Travels and Travel Diaries*, “South America—Argentina,” for his musings about her.) She apparently visited Einstein and Elsa in Berlin at least once, as indicated in a letter she wrote to Einstein in 1939 in which she referred to the visit and recalled the nice time the three of them spent together at his home. She may also have visited in 1928, as a signed photo of him by John Gaudenz, inscribed to “Frau Else Jerusalem” and dated that year, was up for auction at Sotheby’s in May 2001.

Else Jerusalem was a provocative woman for her time. She caused a stir in Europe by talking and writing about sensitive topics such as prostitution and sex education. Born in Vienna in 1877 to a Hungarian wine merchant and his wife, at age sixteen she began to attend classes in literature and philosophy as an auditor at the University of Vienna, which was unusual for a young woman at that time. In 1899, she published her first book of three novellas. In 1902, she published a monograph titled *Give Us the Truth!*, in which she challenged the bourgeois double standard for men and women, and advocated that girls be educated before marriage about sexuality and gender relations. At age thirty-two, in 1909, she published a novel in German titled *The Sacred Scarab* about gambling in a house of prostitution; it went through twenty-two printings within two years, and forty printings by 1926. It appeared in English under the title *The Red House*. She became a popular lecturer and narrator as well as the author of several other books.

Else was married in Vienna in 1901 to Alfred Jerusalem, with whom she had two children who were born soon thereafter. They divorced when the children were still young. She then married Viktor Widakovich in 1910 or 1911, but for professional

reasons kept the name of her first husband, who changed his to “Jansen.” Widakovich may already have been a professor of biology or medicine at the University of Buenos Aires when Else moved there in 1912, though they returned to Europe occasionally. The two children stayed with their biological father.

Sources: Select German Internet sources and rootsweb.com.

Estella Katzenellenbogen (1886–1991)

Katzenellenbogen, born Estella Marcuse, was a wealthy Berlin socialite, married to Max Katzenellenbogen, the director of a German brewery and an influential German businessman. In the Golden Twenties that had swept into the Weimar Republic in the mid-1920s, the couple cultivated a lavish lifestyle, complete with expensive cars and two luxurious homes. They had three children but were divorced in 1929 when Max fell in love with another woman, whom he married the following year.

Einstein and Estella probably met before her divorce, as the Einsteins were acquainted with many of the movers and shakers of Berlin such as the Katzenellenbogens. It is not clear exactly when they began their relationship. Contemporaries knew about the liaison, however, as the two were seen together at concerts, social events, and in Caputh.

Even though Einstein biographies generally dismiss her as a “florist” who owned a chain of flower shops, Estella also made a name for herself as a collector of Impressionist art. She moved to southern California in the late 1930s with her children and became a respected patron of the arts and a collector of Paul Klee paintings, which she had brought from Germany (*see* interview with Vincent Price, 1992, for the Archives of American Art, Smithsonian Institution).

Sources: Einstein Archives 50-799, 30-750, 75-158 and select Internet sources.

Margarete Lebach (1885–1938)

Margarete Lebach was an attractive Austrian divorcée of whom Elsa Einstein was profoundly jealous. Einstein especially took pleasure in sailing with her in his sailboat *Tümmeler*, which he received as a fiftieth birthday present from his friends in Berlin. Whenever Margarete was about to visit, Elsa left in tears to go to Berlin for the day to run errands, too humiliated to be a witness to her husband’s dalliance. Margarete seemed to have no qualms about the arrangement, which further added to Elsa’s frustration.

Margarete Lebach was born in Vienna as Margarete Bachwitz. She married Emil Gottlieb in 1905, with whom she had one child, Teddy, before they were divorced in 1914. She then married Willibald Lebach. Einstein had tried to help them leave Austria for the United States after the *Anschluss*, the annexation of Austria by Germany, in May 1938. A death notice printed by her husband and son announced that she had died prematurely after a long illness, though it gives no date. According to death records, she died on August 17, 1938, in Vienna. Because there are photos of Einstein and Margarete sailing on Huntington, Long Island, taken by well-known photographer Lotte Jacobi in 1937, a year before Margarete’s death, she must have come to the United States on a visit the year before she died.

Ethel Michanowsky (dates not available)

Ethel Michanowsky became a small thorn in Einstein’s side as she continued to pursue him after he had lost interest in her. “It is true that M. [her nickname was ‘Micha’] followed me [to Oxford] and her pursuit of me is getting out of control,” he complained to his stepdaughter Margot in 1931. In a letter of May 24, 1931, from Oxford, Einstein insisted that Ethel stop showering him with gifts, and he ended his letter by signing off “with an absolutely scathing look” (Einstein Archives 84-104). Ethel, fifteen years younger than Einstein, was another Berlin socialite and a friend of Margot Einstein. A handful of friendly letters between the two dating from 1929 to 1939 is filed in the archives. By 1938, Einstein had come to the United States, and Ethel and her son, Georg, were trapped in fascist Italy, also attempting to leave for America. Like so many others desperate to leave Europe, she wrote to Einstein for help. Einstein wrote back saying he was unable to secure any more affidavits for

immigration and hoped they would be able to find another path. The last communication in the archives from Ethel, still writing from Italy, is dated March 1, 1939, when she sent birthday greetings. On October 31, 1940, Einstein sent what appears to be a final letter to Ethel on Ellis Island, writing her that he asked a Jewish women's organization to assist her (Einstein Archives 84-110). She, too, had made it to America.

Toni Mendel (1878–1956)

Toni Mendel, whose maiden name was Antonie Meyer, was born in Cologne, Germany, and married Albert Mendel, the wealthy owner of a clothing factory, in 1898. She was a refined and cultured woman and, along with her husband, was on the membership roster of the Bund Neues Vaterland (BNV; Association for a New Fatherland), a left-of-center, antiwar pacifist organization founded in 1914 (see [Part III](#), Organizational Ties). The organization was favored by many intellectuals, progressive industrialists, and aristocrats. It is possible that the Mendels encountered Einstein and his future wife, Elsa, who were also members of the BNV, at some of the group's meetings. Elsa and Toni were friends, as were Toni's daughter Hertha and Elsa's daughters, Ilse and Margot.

Toni and Albert Mendel were a well-matched couple. Unfortunately, Albert died young, in 1922, and Toni became a wealthy widow at the age of forty-four. Their luxurious villa, located in Wannsee in the southwestern part of Berlin, had been and remained a venue for the gathering of intellectuals and politicians even after Albert's premature death. Toni continued to live in the house with Hertha and Hertha's husband, Dr. Bruno Mendel, and their three children. Bruno was a cousin with the same last name. As a physician and scientist with a keen interest in clinical research, he built a laboratory for himself on the grounds of the estate, and Einstein would visit him there to discuss some of Bruno's experiments. Having had an interest in medicine since his youth, Bruno had been a stretcher-bearer and medic for the Red Cross during the First World War. In 1930, the Mendel villa became the setting for one of the conversations that took place between Einstein and Rabindranath Tagore, which were arranged by Hertha (see also Pastimes, "Music").

Einstein accompanied the widowed Toni to concerts and the theater in her chauffeur-driven limousine. Occasionally, Elsa joined them. The Einsteins, sometimes separately and sometimes together, visited the Mendels regularly at their villa, and once in a while Einstein would spend the night to avoid the long, chauffeur-driven trip back to the city or Caputh on the same day (Einstein never learned to drive a car himself). For the summer of 1928, Toni rented a villa on the beach at Timmendorfer Strand near Scharbeutz in northern Germany, on the Baltic Sea. She invited Einstein, who was recovering from a severe illness, and his family to join her. According to a letter Einstein wrote to his ex-wife, Mileva, at the time, all of the Einstein family members visited there at some point that summer, including his younger son, Eduard.

Most of the correspondence from Einstein to Toni was burned at Einstein's request, probably not until after his death, and he likely disposed of her letters after he read them. The extant correspondence consists only of a handful of letters from 1925 to 1953. The letters do not reflect a serious romance, though many writers have speculated that due to the destruction of these letters a torrid affair must have taken place. What is known for sure is that the two families knew each other well and interacted regularly. Apart from whatever else may have occurred in the early days, over time the two had simply become close friends and confidantes who shared similar interests and read books of mutual interest together.

Toni left Germany and moved to Switzerland in 1931. She lived there until 1938, when she moved to Toronto, Canada. Bruno, Hertha, and their children fled Nazi Germany in April 1933 and moved to the Netherlands. Later they moved to Oakville, Ontario, Canada, where Toni later bought a house as well. Bruno and family returned to the Netherlands in 1950. In 1957, Bruno was elected a fellow of the Royal Society in London. Toni died in Canada in 1956.

Sources: Einstein Archives; Andor Carius, a Mendel family acquaintance and researcher, personal communication.

Margarita Konenkova (ca. 1896–1980)

In 1998, Sotheby's in New York auctioned off a bundle of love letters written by Einstein from November 8, 1945, through July 25, 1946. The letters' recipient was Margarita Konenkova, an alleged Soviet spy with the code name of "Lukas," uncannily similar to "Dukas," Einstein's secretary's last name. Until the time of the auction, it was unknown to the public and even the FBI that the two had had a love affair during the Second World War, and perhaps earlier. The extant letters did not begin until November 1945, after the war and after Konenkova and her husband, Sergei, returned to Moscow on the Soviet government's orders. None of Margarita's letters to Einstein have been found, except for a birthday note written to him in 1939 on behalf of her husband and herself. Not up for auction was a poem Einstein wrote to Margarita on Christmas 1943, in which he addresses her affectionately, and a letter to her of November 1, 1945. All three items are in the Einstein Archives.

Margarita and Sergei, a prominent sculptor who created a bust of Einstein in 1935 that is on display at the Institute for Advanced Study in Princeton, had been living in Greenwich Village in New York since the early 1920s. Margarita was a friend of Einstein's stepdaughter Margot Einstein, who was also a sculptor, and she apparently met Einstein through this friendship. A book published in 1995 by former Soviet spymaster Pavel Sudoplatov, which is by most accounts unreliable, claims Margarita was an agent whose mission had been to procure classified atomic secrets from American scientists such as Einstein and J. Robert Oppenheimer. If she was a spy, she must have been surprised to discover that Einstein had no security clearance, was not privy to classified information, and was himself suspected by J. Edgar Hoover's FBI of being "subversive" (see [Part III](#), Political Contexts, "Postwar and Cold War—FBI's Einstein File"). There is no evidence that Einstein knew she might be leading a double life and may have been attempting to extract secrets from him. He did know, however, that she was eager for him to have contact with Pavel Mikhailov, the Soviet consul in New York. Einstein agreed to meet with Mikhailov to discuss world peace; he also hoped to reach members of the Russian Academy of Sciences through the consul's office. Along with the letters up for auction was a gold wristwatch Einstein apparently gifted to Margarita, one that must have been presented to him during a visit to Caltech in 1931, as it was engraved "Prof. Albert Einstein, Los Angeles, Feb. 15, 1931." Margarita had a history of dalliances with prominent paramours such as composer Sergei Rachmaninoff and opera singer Feodor Chaliapin.

Besides the letters, it is difficult to find reliable information on Margarita. Online sources say she was born in 1896 and died in Moscow in 1980.

Sources: Letters to Konenkova in the Einstein Archives, 85-154 to 85-167; Einstein Archives 84-334 for catalog descriptions and a good synopsis of the auctioned letters; select Internet sources on Sergei Konenkov and on Margarita Konenkova. On Konenkov, see Marie Turbow et al., *The Uncommon Vision of Sergei Konenkov* (New Brunswick, NJ: Rutgers University Press, 2001).

Johanna Fantova (1901–1981)

Johanna Fantova, born as Johanna "Hanne" Bobatsch in Brünn (Brno), now in the Czech Republic, was known around the village of Princeton as Einstein's last significant other. The family of her husband, Otto Fanta, had had connections to Einstein since 1911, when Einstein and his family spent a year in Prague. Otto's parents, Berta and Max, owners of the famous Unicorn Apothecary on Prague's Old Town Square, hosted a *salon* every two weeks in which intellectuals discussed philosophy and other topics of the day. Einstein attended on occasion. Johanna and Otto were married in 1925. In 1929–1930, during a stay in Berlin, Johanna introduced herself to Einstein as the Fantas' daughter-in-law. He hired her to systematically arrange his disorganized library, and took her sailing in Caputh.

In 1939, Johanna immigrated to the United States. Her husband had apparently gone to England just before the outbreak of war and died there in 1940; it is unknown whether she too had gone to England before emigrating. She then visited Einstein in Princeton. Unsure about her future plans, she took Einstein's advice to go to library school and enrolled at the University of North Carolina. In 1944, she was back in Princeton, working as a librarian for several years before becoming the curator of maps at the university's Firestone Library in 1952. She and Einstein continued to have a close relationship until the end of his life, and one of their pleasures was to go sailing on Princeton's Lake Carnegie. He wrote many poems and letters to her, and, as

with Betty Neumann, hand-copied and signed a manuscript for her, presumably knowing the document would eventually provide some income. She sold her letters to Gillett Griffin of Princeton, who donated them to the library. She died in 1981 at the age of eighty.

Johanna Fantova's name became better known in 2004 when librarians at Firestone Library unexpectedly found her old personnel file, which contained a typescript she had written. Except for the introduction, all of it was written in German. To the librarians' surprise, the typescript included not only biographical information about herself but also a journal, written in German, that she had kept of the final year and a half of Einstein's life. The library commissioned Alice Calaprice to provide day-by-day translated summaries of the journal's entries, which were published in the library's quarterly *Journal*. In her journal, Johanna wrote about her almost daily telephone conversations with Einstein, which claimed to reveal his thoughts on aging, politics, various physicists, and other events of the day. Some of her entries reflect previously known information and quotations.

Sources: CPAE, Vol. 5; Princeton University Library Journal 65, no. 1 (Autumn 2003; published in 2004); Fantova manuscript in Firestone Library; Gillett Griffin via Andor Carius, personal communication; excerpts of daily journal entries in Calaprice, The New Quotable Einstein.

Secretaries

Ilse Einstein, 1918–1924?, in Berlin. After Ilse was married in 1924, Einstein had only intermittent secretarial assistance until 1928, and wrote much of his correspondence by hand. Some letters were typed by temporary secretaries, including Siegfried Jacoby and Edwin Sicradz. (*See also* Family, “Family No. 2—Ilse Einstein.”)

Betty Neumann, 1923, six weeks, while Ilse was ill, in Berlin. *CPAE*, Vol. 14, Doc. 103; Einstein Archives 90-782. (*See also* Romantic Interests.)

Helen Dukas, 1928–1955, in Berlin and Princeton. (*See also* Archives.)

Teachers

At the Aargau Cantonal School

August Tuschmid (1855–1939) was a physicist and the rector of the school in Switzerland where Einstein completed the final year of his secondary education. Tuschmid equipped the school with a physics lab, including a small dynamo and other electrotechnical items, to familiarize his pupils with the tools of experimental physics. *Friedrich Mühlberg* (1840–1915) was professor of natural history of whom Einstein was especially fond. *Heinrich Ganter* (1848–1915) was professor of mathematics. Einstein took courses from all three. Under their tutelage, he passed the secondary-school leaving exams, thereby automatically gaining entrance to the Swiss Federal Polytechnical School (ETH) in 1896.

At the Swiss Federal Polytechnical School (ETH)

Adolf Hurwitz (1859–1919) was a professor of higher mathematics at the ETH from 1892 until his death. Einstein, who sometimes played violin duets with Hurwitz's daughter Lisbeth, unsuccessfully tried to obtain a position as his assistant after he finished at the ETH. *Hermann Minkowski* (1864–1909) was a prominent mathematician who created and developed the geometry of numbers, and Einstein used his work in developing relativity theory. His work on space and time, like Einstein's, showed that they were closely linked. After Einstein published his theory of special relativity, it was Minkowski who put it in the mathematical form in which it is usually described today. The metric of special relativity is known as the “Minkowski metric” in his honor. *Heinrich Friedrich Weber* (1843–1912) was Einstein's physics teacher at the ETH. Extensive notes of Weber's lectures by Einstein over two semesters were published in the *CPAE*, Vol. 1, Doc. 37 (ca. December 1897–ca. June

1898; Einstein Archives 3-001 and 3-002), and included the topics of thermodynamics as well as electricity and magnetism. Einstein, however, was disappointed that James Clerk Maxwell's theory of electromagnetism was not part of the curriculum. In the early 1870s, Weber demonstrated that certain substances had unexpectedly small specific heat capacities, except when heated to very high temperatures. Einstein's theoretical explanation of this phenomenon in 1906 was one of the early triumphs of the quantum theory and an important step in the formulation of the third law of thermodynamics. Einstein's paper depended on Weber's experimental results, one of the few occasions on which he provided a detailed discussion (with tables and a figure) of an experimental physicist's results (see [Part II](#), Concepts, "Specific Heat Capacity" and "Third Law of Thermodynamics").

Einstein had initially planned to do his doctoral work under Weber. Although the ETH did not yet have a doctoral program, graduates could formally submit their dissertations to the University of Zurich instead. Possibly because of a disagreement with Weber, Einstein changed his mind about working under his supervision and instead began a dissertation project with Alfred Kleiner at the University of Zurich.

At the University of Zurich

Alfred Kleiner (1849–1916), professor of physics and director of the university's Physics Institute, became Einstein's dissertation adviser. Although Einstein submitted a thesis on molecular forces in gases to him in November 1901, he withdrew it early the next year, around the time his daughter "Lieserl" was born. He submitted a new dissertation in 1905. Kleiner was instrumental in getting Einstein appointed as associate professor of physics at the university in 1909.

Travels and Travel Diaries

Over a twelve-year period, from April 1921 to October 1933, Einstein had the good fortune to set foot on four continents, three of which were new to him.

America, 1921

Einstein did not plan his first trip abroad, in 1921, to speak to Americans about relativity, as one might presume, but to contribute to a cause dear to his heart at the time. In postimperial Germany and elsewhere, the rising tide of anti-Semitism was causing concern for the London-based World Zionist Organisation, headed by Chaim Weizmann, an émigré chemist at the University of Manchester. In an attempt to help alleviate the precarious situation for Jewish students and scholars in Europe, especially those coming from East European countries, the Zionist leadership sought to establish a university in Jerusalem in the British mandate of Palestine. Weizmann proposed that Einstein accompany him to America on a fund-raising tour for the prospective institution. He was well aware that the physicist's soaring fame would attract more attention among American Jews than a political delegation of Zionist leaders.

As a staunch opponent of nationalism, Einstein did not agree with all of the Zionist precepts (see [Part III](#), Jewish Identity and Ties, "The Cultural Zionist Ideal"), and he expressed his ambivalence about a Zionist-sponsored trip to friends. Yet, he could not resist the temptation of advancing the educational dreams of his kinsmen, and he—and Elsa—accepted the invitation. When news of his upcoming visit reached America, he received an avalanche of requests to lecture on relativity at various institutions. He accepted several such calls in the cities that were already on the delegation's itinerary.

Upon his arrival in New York Harbor on the SS *Rotterdam* on April 2 ([fig. 32](#)), after a nine-day voyage from England, Einstein received a tumultuous welcome and a "Freedom of the City" key from Mayor John Hylan. His most prominent scientific appearances took place in Princeton, where he gave five lectures on relativity at Princeton University from May 9 to May 15, and in Washington, DC, at a talk delivered at the National Academy of Sciences. His reception by nonscientists outside the Jewish community, especially politicians and even President Warren Harding, was occasionally cold: many of them still considered postwar Germans the enemy.

Weizmann and Einstein also traveled to Chicago, Boston, Hartford, Cleveland, and Philadelphia before returning to New York for the trip home on the *SS Celtic*. Because Weizmann was aware of Einstein's reservations about the Zionist agenda, he did not invite the physicist to speak during their public appearances. Einstein conceded that he had offered himself up "as a prize ox" for the cause. He did not keep a travel diary on this journey, but back at home he gave an interview to a Dutch newspaper about his impressions of America. In the article, the correspondent quoted him as labeling American men "the lapdogs of their wives," causing him embarrassment when the translation crossed the pond. He then retracted the statement and heaped huge praise on all Americans.



MAP 2. Einstein's extensive travels in the 1920s, as described in his travel diaries. Though he did not travel to the two solar eclipse sites in West Africa and Brazil in May 1919, they are included here so readers can see their location. The expeditions to the sites provided data in agreement with Einstein's theory of general relativity. Also included is Gothenburg, Sweden, where Einstein traveled in 1923 to belatedly accept his 1921 Nobel Prize.



FIGURE 32. Einstein with Elsa arriving in the United States on the SS *Rotterdam* for their first visit, 1921. (Wikimedia Commons; press photo purchased by Library of Congress)

Asia, 1922–1923: The Far East and Palestine

Einstein's next trip, to Asia, came soon, in 1922–1923, but lasted much longer than his American sojourn. Continuing to feel the pressures of anti-Semitism in Berlin, he accepted a generous offer from the Japanese publishing house Kaizō-sha to visit Japan and give several public lectures there. It was an opportunity to leave Germany for almost half a year. After much negotiation about logistics and compensation, Chinese academics also invited him to lecture in Shanghai and Beijing, but because of miscommunications, the China lectures, in the end, did not take place.

Einstein and Elsa left on the long sea voyage from Marseille on October 7, 1922, on the Japanese liner *Kitano Maru*. Among his travel accessories was a blank booklet that he used as a travel diary, the first time he undertook such a writing endeavor. As the diary reveals, he not only reported on the weather and sea conditions, but he also worked consistently on a unified field theory. After stopping at Port Said at the northern terminus of the Suez Canal, the ship steamed south into the Red Sea, then east through the Gulf of Aden and across the Arabian Sea. When the vessel approached the equator, Einstein became interested in the tropical weather patterns, diligently recording his observations in his diary. Toward the end of the month, the ship stopped at its first port of call in Colombo, the capital of today's Sri Lanka. This is the first time the travelers had a chance to set foot on land after three weeks at sea. The poverty and human misery Einstein encountered here rattled him—it was a culture shock he hadn't experienced before. On his way to Singapore, off the coast of Sumatra, Einstein witnessed his first *fata morgana*, a mirage seen in a narrow band over the horizon.

On November 2, the ship arrived at the next stop, Singapore. When Chaim Weizmann had learned earlier that the Einsteins' trip would have a one-day layover there, he seized the opportunity to contact members of the Jewish community: it was

a good place for Einstein to procure donations for a future Hebrew University. Einstein was a polite guest of the contingent that greeted him, and, after many festivities and much hand shaking, he was able to extract a handsome donation from the community's wealthiest member, Menasseh Meyer. A week later, he and Elsa disembarked on a stopover in Hong Kong, and they were again greeted by a delegation of Jews who showered them with attention and sightseeing excursions. The achievements of the British administration of Hong Kong and the natural beauty of the colony impressed Einstein, but the substandard working and living conditions of the Chinese people startled him. He saw them as "gentle, dull, and neglected" as they pursued their "grueling struggle for existence." Yet he was also prescient: he concluded that the Chinese were capable of supplanting every other nation, thanks to their diligence, their modest expectations, and their fecundity (Eisinger, *Einstein on the Road*, pp. 30–33). His impressions during a brief stay in Shanghai were the same.

The *Kitano Maru* headed farther east, crossing the Yellow Sea and arriving in Kobe, Japan, on November 17. After leaving Kobe, the Einsteins went north for a one-day stay in Kyoto and then embarked on a ten-hour train trip to Tokyo. The Japanese had spent months preparing for Einstein's arrival and visit. Einstein became enchanted with everything he saw around him, including Japanese women: "This flowerlike being: here the ordinary mortal must defer to the poet's words." He claimed to have seen, for the first time, "a happy and healthy society whose members are fully absorbed in it." Eight years later, when Japanese schoolchildren asked him for a message, he recalled his happy memories in a letter to them, ending with "I, an old man, hope that your generation will someday put mine to shame." (See also Calaprice, *The Ultimate Quotable Einstein*, pp. 78, 437–438.)

The purpose of his trip, however, was to inform Japanese scientists about relativity theory, and he had ample opportunity to do so. In Tokyo, he gave two public lectures. The first, on November 19, was attended by two thousand people at Keio University. Physicist Yun (or Jun) Ishiwara translated the lecture from German into Japanese after each sentence, a dismally long process that turned the talk into a four-hour ordeal. Einstein was also feted at receptions, including one hosted by the publishing house that had sponsored his trip, and he and Elsa were given opportunities to attend museums, tea ceremonies, and other festive cultural events, all of which he enjoyed immensely. On November 24, he gave his second public lecture, held at the Youth Assembly Hall. On November 25, he began a series of six daily talks at the Physics Institute of Tokyo Imperial University, which ended his scientific lecturing obligations in the city. His last day in Tokyo was December 1. That evening, at a lavish farewell dinner, he played Beethoven's *Kreutzer Sonata* for his hosts and the other attendees.

After Tokyo, Einstein still had more Japanese cities to see and people to meet. He went to Sendai to give another public lecture, then to Nikko and the countryside for some sightseeing before going to Nagoya. The Nagoya public lecture was held in an unheated arena that was normally the venue for Sumo wrestling and other sports, and he endured the December cold by wearing his coat during his talk. He then returned to Kyoto, where, on December 10, in another frigid lecture hall, he gave a lecture on the philosophy of relativity theory. The event was made even more challenging by Ishiwara's cumbersome translating efforts, again extending the talk, like the one in Tokyo, to four hours. On the 14th, after returning from brief trips to lecture in Osaka and Kobe, he gave an extemporaneous talk at a student reception about how he "created the theory of relativity." On December 24, he lectured in Fukuoka. On December 25, he played the violin at a children's Christmas party at the YMCA in Moji. Finally, on December 28, his last night in Japan, Einstein again played his violin during an evening event with Japanese businessmen in Moji. The next day, he and Elsa left Japan from Moji on the SS *Haruna Maru*.

ON TO PALESTINE

On their homeward-bound trip, the Einsteins had a two-week stopover in Palestine before going to Spain and from there back to Berlin. Their ship again made short stops in Shanghai, Hong Kong, Singapore, Malaya, and Ceylon (Sri Lanka). Heading west over the Arabian Sea and north through the Red Sea, the Gulf of Suez, and the Suez Canal, the *Haruna Maru* steamed toward Port Said. On February 1, Einstein and Elsa found themselves in Egypt again. From Kantara on the western side of the canal,

they took a ferry across to the eastern side, then before midnight boarded a train to Lod (Lydda) in Palestine, slightly inland from the Mediterranean coast, east of Tel Aviv. They arrived in Lod on the morning of February 2, where a welcoming committee boarded the train and accompanied the Einsteins on their way up the hills to Jerusalem.

The next day was devoted to a sightseeing tour of Jerusalem. A visit to the Western Wall, where Orthodox Jewish men prayed and davened, suggested to him a deplorable scene of “dull-witted kinsmen” who had “only a past but no present.” Strolling through the old quarters of the city, he noted its “strange oriental air,” finding the streets putrid and noisy. While taking further sightseeing trips to the Jordan Valley, Jericho, desert landscapes, Jewish settlements, Bedouin encampments, Tel Aviv, Haifa, the Sea of Galilee, and various holy sites and schools in the Old City and surrounding areas, Einstein also met with Jewish leaders and gave lectures at Mount Scopus and at the Lämél School in Jerusalem, and in Tel Aviv. He also visited farm settlements (fig. 33). The idealism of the communal spirit of their inhabitants impressed him, but he felt they were an enterprise that wouldn’t last far into the future, considering the hunger, disease, and debt the people there suffered.



FIGURE 33. Visiting the farm settlement Rishon Letzion with Elsa in Palestine, 1923. (Central Zionist Archives)

Einstein had felt at ease in Palestine because he was able to converse in German with many of the people he met and befriended. He noted in his diary that he took time to talk not only to academics, businessmen, and intelligent laborers, but also to beautiful young women. The Zionists took pains to make the Einsteins feel welcome, hoping they might convince them to make aliyah to Palestine. On Einstein’s last night there, they pressed him on the matter, to which he replied: “The heart says yes, but reason says no.” More than two decades later, after the establishment of the Jewish state and his negative views on some of Zionism’s political goals were better known, the leadership wasn’t quite as eager to have him settle in Israel but still felt obliged to offer the world’s most prominent Jew the ceremonial position of the presidency. “Tell me what to do if he says yes. I had to offer the post to him because it is impossible not to. But if he accepts, we’re in for trouble,” exclaimed David Ben-Gurion to Yitzak Navon after Ambassador Abba Eban was instructed to make the offer (see Holton and Elkana, *Albert Einstein*, p. 295). Fearing Einstein’s candor in the face of policies that might run counter to the dictates of his conscience, Ben-Gurion was relieved when he turned down the offer.

Spain, 1923

Einstein's account of his time in Spain does not take up as much space in his travel journal as the earlier countries, perhaps because his Spanish visit was the last leg of his journey back home after an exhausting, emotionally charged, and very long trip to exotic countries. He recorded snippets and notes but did not wax poetic and showed little awe and surprise. Still, he remarked at the end of his stay that "it was lovely!"

The Einsteins had had a strenuous journey from Jerusalem to Suez and Port Said. Elsa had become gravely ill with a high fever while en route to Port Said. After some rest, she recovered, and they boarded the SS *Oranje* bound for Toulon in France. During stops in French ports, Einstein sensed that Germans were not welcome, and he was reminded once again of the troubles of a different kind that still lay ahead back home. They took the train from Toulon and arrived in Barcelona on February 22. During his six-day stay there, Einstein gave three lectures in French at the Institut d'Estudis Catalans, intended for scientists but attended by a throng of the curious. He also gave a talk at the Academy of Sciences on the philosophical and cosmological implications of relativity. The Einsteins spent their leisure time sightseeing around the old city, usually accompanied by the German consul and his wife.

On March 1, they arrived in Madrid, where the capital's dignitaries and Einstein's friend Blas Cabrera welcomed them. Here, among previously scheduled activities, Einstein and Elsa found time to visit cousins who had settled in the city. Three lectures were also on the agenda, as was a public conversation at the Academy of Sciences about the state of physics. The king, other members of the royal family, and many academics were in the audience and listened to him intently. King Alfonso XIII, whom Einstein and Elsa later visited at the royal palace, presented Einstein with a certificate of membership in the Spanish academy, and several days later, on March 8, the university awarded him an honorary doctorate. It became evident to Einstein that socializing with glitterati and aristocrats was important in Spanish society, and he was obligated to participate even if he felt uncomfortable among them. Fortunately, he had his violin along and on one occasion found some relief in playing an improvised duet with a Spanish violinist.

Saragossa (Zaragoza) was next on the itinerary. The Einsteins left Madrid and arrived in the city on March 12. Einstein was scheduled to give three lectures here, but it became apparent after the second lecture that the audience was not able to follow his explanations. Therefore, the third lecture was canceled. His hosts continued to fete him, nevertheless, showering him with accolades and honoring him with a corresponding membership in their Academy of Sciences. The evening before he left Saragossa, Einstein again played the violin, this time accompanied by a visiting pianist. The following day, after almost half a year on the road—and much of it at sea—the Einsteins returned to Berlin via Barcelona and Zurich.

According to Thomas Glick (*Einstein in Spain*), Einstein's visit to Spain in 1923 helped to stimulate a "recovery of science" in the country between two periods of political repression. Because of Einstein's charisma and intellectual appeal, not only scientists and engineers but also ordinary citizens took a renewed interest in the role of science in modernization.

South America, 1925

Einstein undertook his trip to South America alone. His stepdaughter Margot had looked forward to going, but an illness forced her to stay behind. Einstein's travel diary thus became his only constant companion and confidant.

The trip began on March 6, 1925, in Hamburg on the luxury liner *Cap Polonio*. Einstein was scheduled to visit Argentina, Brazil, and Uruguay, countries whose officials had invited him to give a series of lectures explaining his theories. He was fortunate to have found almost immediately two fellow passengers onboard who were to his liking: one an academic psychologist and philosopher named Carl Jesinghaus, and the other a Viennese woman known widely for her feminist writings on prostitution and sex education, Else Jerusalem (*see also* Romantic Interests). The latter was two years his senior and lived with her second husband in Buenos Aires. These two passengers served as Einstein's table companions and occasional raconteurs on the decks, but Einstein told his diary he was keeping mostly to himself, reading and

working on a problem in Riemannian geometry and a unified field theory. Before reaching South American shores, the ship stopped in Bilbao in northern Spain and then in Lisbon, where the passengers had time to sightsee.

Einstein showed his social side while aboard. He did not shy away from mingling with the passengers and came to enjoy the company of Else Jerusalem, whom he referred to as the “Panther Cat” in his journal. Like his Elsa at home, this Else also liked to give recitations, and she read one of her writings to Einstein and the captain on Einstein’s forty-sixth birthday on March 14. To cap off his birthday celebration, he assembled three other passengers to form a “moderately successful” string quartet for the rest of the evening. After that, daily quartet playing with other passengers became routine.

When the ship docked in Rio de Janeiro in Brazil for a few hours on March 22—more than two weeks had passed since the departure from Hamburg—a group of engineers and doctors welcomed Einstein and took him on a quick sightseeing tour. The highlight was a visit to the lush botanic garden, and a treat for his senses was the mixture of people of various ethnicities. He wrote in his diary that an “indescribable wealth of impressions” rewarded him in a very short time.

ARGENTINA

On Einstein’s arrival in Buenos Aires, the usual Jewish and academic delegations and hosts greeted him. They were more than eager to be in his company and show him around.

Finding the proposed activities and invitations for his visit too ambitious, he turned down any unnecessary engagements. He showed up only for his lectures and for social occasions that promised to be relaxing and enjoyable. The beguiling Else Jerusalem was present at some. Overall, however, according to his journal, he found the people superficial in their tastes. A visit to the Jewish quarter left him unimpressed as well. After meeting a number of Zionists, he concluded the Jews here had “lost their soul along with their lice.” On April 1, he experienced his first flight in an airplane—a seaplane that circled around the city at 1,000 meters, a palpable thrill. He took excursions to La Plata and Córdoba, Zionists honored him at their gatherings, and academics at the university in Buenos Aires elected him as a foreign member of the National Academy of Sciences. He also attended a reception at the German Embassy that Germans essentially boycotted because of their opposition to Einstein’s pacifism. After the event, he noted in his diary, “I’m a stinking flower to them, but they continue to stick me into their buttonholes anyway.”

Einstein was so busy for two weeks that he had been neglecting the Panther Cat, who failed to show up at two social occasions at which Einstein had expected her. Since he was about to leave Buenos Aires, he had brought a going-away gift—a verse he had composed for her in German and written on a photograph of himself:

This is for the Panther Cat,
Even though she went to hide
In the jungle harsh and wild.
This picture’s for her
In spite of that.

After five weeks in Argentina, Einstein looked forward to seeing Uruguay.

URUGUAY

On April 24, Einstein arrived in Montevideo, where he turned down the chance to stay in an elegant hotel in order to visit with a Russian-Jewish family, the Rosenblatts, for a few days. In contrast to Argentina, he loved Uruguay, where he found the people to be genuinely warm, humane, and unpretentious, traits he felt were more common in smaller countries. The liberal Uruguayan government’s social programs were more to his liking: protection for illegitimate children, strict separation between church and state, and outstanding care for children and the elderly. Einstein gave three lectures here and met with government and academic leaders, members of the German and Jewish communities, and attended the usual receptions, banquets, and sightseeing excursions. His six days here were so eventful that he did not have enough time to write more about his experiences in his diary. He

left Montevideo on May 1 on a small French liner, the *Valdivia*, whose captain he liked, but the food and toilet facilities did not meet his expectations.

BRAZIL

Einstein prepared himself for an eight-day stay in Rio de Janeiro as the *Valdivia* anchored on May 4. After settling into a luxurious hotel, he set out to fulfill a string of obligations and meetings with government, academic, and German and Jewish leaders. Sightseeing excursions, including one to the natural history museum, showed him the best of Rio. His public lecture on relativity was well attended, if mostly by curiosity seekers who even brought their small children along. At a reception at the Academy of Sciences, he found the speakers to be verbose and the speeches irrelevant. He confessed to his diary that it was becoming difficult for him to be constantly around hordes of people he did not know. Visits to the National Observatory, a biomedical research institute, and a road trip around Rio the day before he left South America were more to his liking.

On May 12, he boarded the *Cap Norte* bound for Europe. In two weeks, he was back in Berlin after completing a trip that was more strenuous than he had anticipated.

Back to America, 1930–1931

It had been almost ten years since Einstein's first trip to America in 1921. This time, in addition to Elsa, he was also accompanied by Helen Dukas and his "calculator," Walther Mayer, a mathematician who assisted him with his work. The final destination this time was California, with a stop in New York, for which they set out on the SS *Belgenland*. The small contingent left Europe at Antwerp, Belgium, on December 2, 1930. After short stops in Southampton and Cherbourg, the ship steered out to the open sea.

Throughout this journey, Einstein dealt almost daily with telegrams urging him to give lectures or interviews—enough of them to cause disagreements with Elsa on how to handle the invitations. The sea was mostly turbulent, but it availed him of the chance to stay in his cabin, respond to the telegrams, and work on his field equations. On the last evening, passengers tossed balloons around the deck and gave repeated farewell toasts before docking in New York, where Prohibition was still in effect.

The arrival and reception in New York turned out to be an unexpected nightmare. Reporters and photographers pounced on Einstein like "a pack of hungry wolves" while Elsa uneasily hovered over him, and there was no end to inane questions. The group spent four days in the city, sightseeing and convening with the various dignitaries who were eager to meet Einstein. Among the highlights was a visit to the Riverside Church. Here, among other worthy souls, Einstein's image had recently been carved in stone in the tympanum over an entrance to the church (see photo in section on Fame, *above*). The group also went to the Metropolitan Opera to see *Carmen*, met with and heard Arturo Toscanini conduct Beethoven's *Pastoral* symphony, and received another key to the city from Mayor Jimmy Walker at City Hall. Einstein listened to accolades from Nicholas Butler, the president of Columbia University, who called him a "visiting monarch of the mind." They attended a Zionist rally, "a farcical affair," according to Einstein's diary entry; to the Metropolitan Museum of Art; to the NBC studios, where Einstein delivered a radio address to Zionist youth, whom he urged to cultivate good relations with the Arab population in Palestine; and to Madison Square Garden for an elaborate Hanukkah celebration. Einstein also met with Abraham Flexner to discuss plans for the new research institute that was being established in Princeton, New Jersey; with John D. Rockefeller to learn the rules about scholarships; with the Austrian-born violinist and composer Fritz Kreisler; and with Bengali Nobel laureate Rabindranath Tagore, who happened to be visiting New York at the same time. Finally, Einstein gave a speech on "militant pacifism" to the New History Society, to which he received a rousing ovation.

On December 15, the small Einstein entourage left New York behind and steamed west toward warmer weather. They stopped in Havana for a night on December 19 to enjoy the mild Cuban winter, but even here there were interviews and obligations. Einstein noted the great disparity between the rich and the poor, the latter nevertheless looking happy because, in his estimation, the climate was good and there were many bananas to eat.

On December 20, they were at sea again, experiencing a tropical storm and a heat wave over the next three days. Einstein often mused in his travel journal about the beauty of stormy weather, the sea, and marine life. On the 23rd, they steamed through the locks of the Panama Canal and anchored for a short stay in a town that today is Panama City. Christmas at sea presented Einstein with an occasion to play the violin with a small ensemble of fellow passengers.

Early on December 31, the ship arrived in San Diego to great fanfare, and from there Einstein and his group were driven to Pasadena, where they stayed until the end of February 1931. The group enjoyed the pleasures of spending the winter in Pasadena rather than Berlin or New York. Yet they took the time to see other nearby points of interest as well. Einstein and Elsa went to the Mount Wilson Observatory, where Edwin Hubble personally showed them the 100-inch Hooker telescope ([fig. 34](#)). They also spent time in Palm Springs and the surrounding desert areas. Both the desert and mountain views captivated Einstein, especially the curious shapes and textures of the cactuses and Joshua trees, and the light cast by the sun onto the mountains and foothills.

At the end of February, the Einsteins left Pasadena by train, bound for New York, where they enjoyed a brief stay. En route they stopped at the Grand Canyon to pose with a group of Hopi Indians ([fig. 35](#)). At midnight on March 4, 1931, they left for Europe on the SS *Deutschland* and arrived home on his birthday, March 14.

Oxford, May 1931

In May 1931, Einstein went to England by ship for a month's stay, mainly to deliver the prestigious Rhodes Lectures at Oxford (see [Part II](#), Lectures). He arrived on the SS *Albert Ballin* on May 1 in Southampton and was driven to Oxford in a Rolls Royce. Einstein was an Anglophile, and he appreciated both the vigorous intellectual environment as well as the natural environment of the Oxford countryside. He gave his first lecture on May 9, focusing on relativity theory and speaking extemporaneously, and gave two more lectures later that month. During this time, the university bestowed upon him an honorary doctorate of science. In between his lecturing obligations, he enjoyed many musical evenings playing a borrowed violin. He had a satisfactory month of May in England, and steamed back home on the SS *Hamburg* at the end of the month.

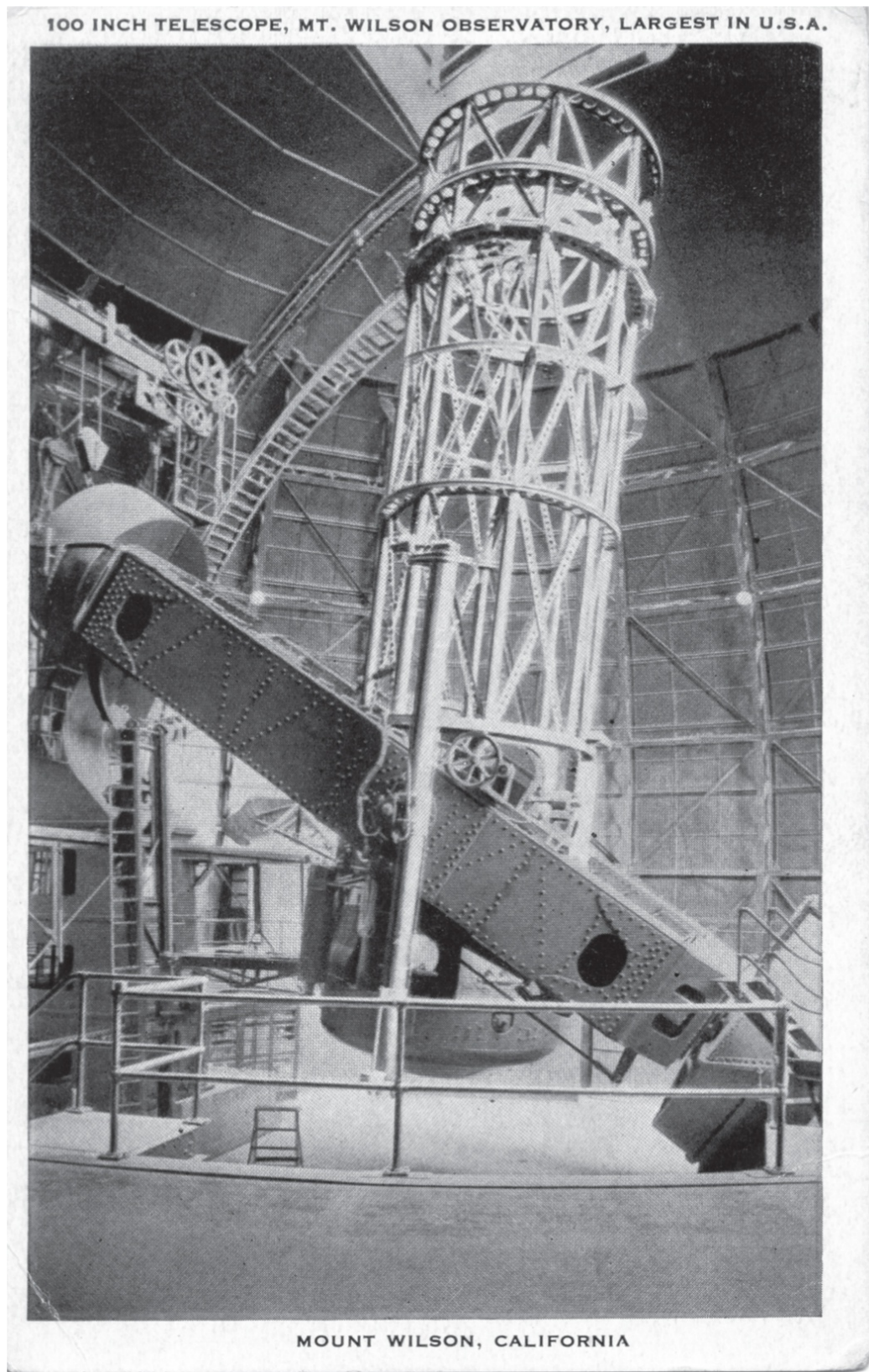


FIGURE 34. Vintage postcard of the 100-inch Hooker telescope at Mount Wilson. Edwin Hubble used it in the 1920s to measure the distances and motions of the galaxies, proving, by 1929, that the universe is expanding, a result that surprised Einstein, who visited Hubble at Mount Wilson in 1931. Today, the telescope is a National Mechanical Engineering Landmark and is still used in research.

America, 1931–1932

On this trip, Einstein chose to avoid the hassles of New York and booked direct passage to Los Angeles for himself and Elsa on the MS *Portland*, leaving from Antwerp. The ship was under-booked and carried only ten paying passengers. Even though the sea was often turbulent, the voyage was unusually relaxing for Einstein, thanks to the company of a few amicable passengers and the eclectic selection of books he had brought with him. The ship made stops in three Central American countries—Panama, Honduras, and El Salvador, where the heat was oppressive this time of year. Like the previous year, the Einsteins spent Christmas on an ocean liner. They disembarked in Los Angeles on the morning of December 31 after spending a month at sea. Their time in Pasadena was again filled with visits and visitors, lectures, another trip to Palm Springs, and musical evenings playing the violin. The publicity surrounding Einstein was much more subdued than the year before, giving him and Elsa more time to relax. They left Los Angeles on March 4, 1932, on the MS *San Francisco*, arriving back in Germany at the end of the month.



FIGURE 35. Posing with a group of Hopi Indians at Hopi House, Grand Canyon, Arizona, February 28, 1931. The Hopis anointed Einstein as their “Great Relative.” (Courtesy of the Palace of the Governors Photo Archives (NMHM/DCA), neg. no. 038193)

America, 1932–1933

Einstein and Elsa made their last trip to Pasadena in December 1932. At this time, conservative Americans still did not trust him. For example, the Women Patriot Corporation, under the leadership of Mrs. Randolph Frothingham, urgently wrote the U.S. State Department that Albert Einstein should be kept out of the country. The group condemned him as the ringleader of an anarcho-communist plot, and informed the government that the theory of relativity is subversive and was designed to promote lawlessness and destroy Church and State. Einstein famously noted via the Associated Press that “never yet have I experienced from the fair sex such energetic rejection of my advances; or if I have, never from so many at once” (ca. October

1932; Einstein Archives 28-213).

During this trip, Einstein made his final entries into his travel diaries. The ones he recorded while onboard ended only a week after they had set out to sea on the MS *Oakland*. They left from Bremerhaven on December 10, on a route that was similar to the previous year's, with a stop in Antwerp on December 12. Here friends and family came aboard to wish the Einsteins bon voyage. They left Belgium on December 14, and arrived in Los Angeles on January 9, some four weeks later. While living in Pasadena, Einstein wrote a few additional diary entries, then stopped. He participated in only one public discussion, which focused on the economy and was organized by southern California's university students. Even back then, it seemed to him that technology was responsible for the Depression because it caused unemployment, which resulted in lower purchasing power and more layoffs. On this trip, Einstein met J. Robert Oppenheimer and Linus Pauling, among other notables, and, as he had done before, dined at the home of Upton Sinclair. By now, his California stay routinely included a road trip to Palm Springs and meetings with celebrities.

Einstein's stay in Pasadena ended on March 11. By then he had already decided and announced that he and Elsa would not return to Berlin, though they did return to Europe temporarily. They took up short-term residence in Belgium before immigrating to the United States. (See *Citizenships and Immigration to the United States*, *above*, for the rest of the story about his last days in Europe.)

Sources: Travel Diaries, Einstein Archives 5-253, 5-255, 5-256, 5-258, 5-259, 29-144, 34-728.1; Eisinger, *Einstein on the Road*; CPAE, Vol. 13; Hu, *China and Einstein*; Glick, *Einstein in Spain*.

Death

Einstein died at Princeton Hospital in the early morning of April 18, 1955, of a ruptured arteriosclerotic aneurysm of the abdominal aorta. He was seventy-six years old. (See Death Certificate on p. 9)

After an autopsy, during which his brain and eyes were removed, his body was taken to the Mather-Hodge Funeral Home in Princeton, which is still in business today. Arrangements were quickly made to have the body cremated in Trenton on the same day, and Einstein's ashes were scattered at an undisclosed place by two friends, Otto Nathan and Paul Oppenheim.

The last person to see Einstein alive was his nurse, Alberta Roszel, who reported, "He gave two breaths and expired," according to the *New York Times* obituary of April 19, 1955. His stepdaughter Margot described his last hours this way in a letter the same month to family friend Hedwig Born: "He ... waited for his end as for an impending natural event. He faced death quietly and modestly, and was fearless, as he had been in life. He left this world without sentimentality and without regrets" (see G. Born, ed., *Born-Einstein Letters*, p. 229). Helen Dukas also left a written account of Einstein's last days (see *below*).

A memorial concert took place at McCarter Theater in Princeton later that year, on December 17, 1955, and featured the following program: Robert Casadesus, piano, and the Princeton University Orchestra performing Mozart's Coronation Concerto (concerto for piano and orchestra in D Major) and Bach's Sonatina from Cantata no. 106 "Actus Tragicus." Also played were Haydn's Symphony no. 104 in D Major and Corelli's Concerto Grosso no. 8 ("Christmas"—presumably because of the holiday season).

Additional sources: *California Monthly*, December 1995: 27–28; *Harper's* magazine, October 1997; *New York Times*, June 18, 1999.

An Account of Einstein's Last Days by Helen Dukas

By the end of 1948, it was confirmed through an operation that [Einstein] had an aneurysm, though it was not considered potentially dangerous for another year or year and a half.

About four weeks ago, he complained about mild pain, which we attributed to his troublesome gall bladder and liver problems. Around April

11 or 12 he told me that he had fairly strong pain in the inguinal [lower abdominal] region—that is, in an area that had never bothered him before. He suggested, “It’s certainly the aorta.” He did not allow me, however, to call the doctor. I called Margot [Einstein’s stepdaughter] in the hospital nevertheless and told her to tell the doctor, whom she saw daily, so he would at least know. (A week earlier, he had had a blood test, which had shown that everything was perfect.) On the morning of the 13th he again said that he had pain during the night, more when he was lying down than when he was standing, but now he was quite all right. In spite of this I called Margot again to remind her not to forget to tell Dr. Dean (she had already done so).

He [Einstein] stayed home that day because he was awaiting the Israeli consul, as well as an old friend who was visiting from Europe. The visitors left at 1 o’clock, and he complained of overwhelming tiredness and had little appetite. After lunch he took a nap as always, at around 2 o’clock. At 3:30, I heard him walk to the bathroom—this is where he collapsed. The doctor came very quickly—he was not at home, but he was reached right away—but to me it seemed to take an eternity. He knew immediately what the problem was and called two colleagues. I was present at their medical colloquium, at which they decided to call some doctors in New York. I called a friend to spend the night at the house with me because the doctors did not want me to be alone with him—they also did not want to transport him. They thought that it was a small hemorrhage (the blood pressure and pulse remained normal) that might reabsorb. In the evening, two doctors came from New York and consulted with Dr. Dean, who, with my “assistance,” took an electrocardiogram.

The night passed quite normally with the help of a shot of morphine [for Einstein]. I set up a makeshift bed for myself in the study, which the professor found ridiculous. He accepted it only after I told him that I would sleep better this way, rather than in my faraway room, where I would just be restless trying to hear his movements. He also did not want me to make extra trips down to the kitchen to get ice (he was dehydrated and it was the only thing, besides spoonful of mineral water, that he could suck on in little pieces). But I did not pay attention [to his request] in this case.

The next day, the New York doctors came once again, along with his old doctor from Berlin, Dr. Ehrmann. They also wanted to bring in a famous surgeon, a heart specialist. The professor did not want anything to do with any of this right from the beginning, but he listened good-naturedly to all of them. Later he asked our doctor if it will be “a horrible” death. The answer was: perhaps; one doesn’t know. Maybe only a minute, maybe hours, maybe days. He should know that the pain of an internal hemorrhage is the worst pain one can have. He endured the pain with a smile, and unfortunately sometimes refused a shot of morphine. The night from Thursday to Friday was bearable again—but, unfortunately, he had refused a shot in the afternoon and could barely stand the pain until the doctor came again in the evening and gave him one. The doctor would not have paid attention to any such refusals from his other patients, but due to his respect for the professor, he did not want to do anything against his will.

Thursday night I went in to see him because I heard him move around, and he told me: “You’re really hysterical—I have to pass on sometime, and it doesn’t really matter when.” I told him I was up anyway, that I had just gone to the bathroom. I don’t know if he believed me, but he pretended he did. In the morning, he said he still had severe pain, but it had now localized in the spleen area as always, and he did not feel so ill anymore. When I came in later in the morning, he was lying there, looking bright yellow, and he said he felt so very ill again that he could not lift his head and the pain was unbearable. I rushed to the telephone and luckily reached the doctor personally. He came right away, but don’t ask how long it seemed to me. In the meantime, he [Einstein] became so asthenic that the only good thing about it was that he could not feel the pain as much. The doctor now confirmed a swollen gall bladder (as we were told later, after the hemorrhage, the gall bladder became clogged and a rupture could have been

fatal). The asthenia was a result of early dehydration.

The doctor overruled the professor's resistance against going to the hospital by telling him that he would need to be fed intravenously; that it makes him very unhappy that he is experiencing so much pain and that he can't relieve him of it immediately; and, third, that the situation had become too much for me to handle (this became the decisive factor). He gave him a shot, ordered a room and an ambulance, and, half an hour later, he was in the hospital, where they immediately began the intravenous feeding. On the way, in the ambulance, he held a lively conversation with one of the men (all were volunteers), who happened to be a political economist at the university. It was unbelievable....

He fared so much better in the hospital because they could quickly give him his shots (although he refused one there as well), and because the IV naturally provided some relief. On Saturday he even called me at home himself, asking me to bring his eyeglasses. And on Sunday he asked for his writing paraphernalia. He greeted Margot when she was brought to him in her wheelchair. "You're arriving in style!" he said, all while he was still asthenic. He told her about the proposed surgery and said, "How undignified. I'm going when I want to go—elegantly!"

Margot can tell you about this incident better than I can. By his greatness and simplicity, he awaited death with a smile and as a natural event: how could we be anything but calm! On Friday afternoon, Margot called his son [Hans Albert], who took the next plane and was with us already on Saturday morning. This was a big comfort to us all. The professor was not at all surprised to see him, but was only happy. On Sunday, his condition and appearance really seemed better. Still, he looked stressed—even a child could see that. During the afternoon, he and his son talked about scientific matters, then later he talked politics with Otto Nathan, read the newspaper, etc. He even took liquid nourishment by himself by mouth. I can't say that we were hopeful, because we knew that this was at most a temporary reprieve, but one so much likes to believe in miracles.

During the night at 1:25, Dr. Dean telephoned me to let me know that the professor died peacefully in his sleep. To my embarrassment, I have to admit that I collapsed, even if only for a short time. I don't know how I would have made it through the night without Adn [Hans Albert's nickname, origin unknown], who sat next to me and talked with me—it was as if his father were talking with me. He then took charge of everything, called New York, etc. At seven o'clock, Otto Nathan had already arrived, and at eight o'clock we drove to the hospital. Dr. Dean had taken it upon himself to tell Margot early in the morning, and we wanted to be there.

What followed is a nightmare, as soon as the news became known, and I don't want to bother you with that today. We were, however, able to have the cremation performed that same day in peace and quiet, with only the next of kin present. [End of Dukas's account.]

Source: *Translated from the original German by Alice Calaprice. Einstein Archives 39-071*

Removal of the Brain

The story of the removal of Einstein's brain has become well known, but we will repeat it here. Briefly, Princeton Hospital's pathologist, Dr. Thomas Harvey, performed an autopsy and, without permission from the family or hospital, removed the brain and stored it in formaldehyde in a Mason jar (or in Tupperware, depending on which account you read) until shortly before his own death in 2007. After taking photos of the brain, he fragmented it in a lab at the University of Pennsylvania and over time gave small sections of it to various researchers. In 2010, Harvey's heirs transferred the remainder of the brain, including fourteen of the photographs he had taken in 1955, to the National Museum of Health and Medicine. The Mütter Museum of medical history in Philadelphia also acquired forty-six small sections of the brain from one of the researchers and put them on permanent display in 2011. Harvey also took the eyes and apparently presented them to Dr. Henry Abrams, Einstein's

ophthalmologist, who died in 2009. We could find no reliable record of the current location of the eyes, though as late as 2012 they were rumored to be stored in a safe deposit box in New York City.

After the cremation, the Einstein family learned about the removal of the brain and agreed to let Dr. Harvey keep it for scientific study. This consent apparently gave the doctor legal right to keep the brain, though Princeton Hospital eventually fired him for doing the deed. For thirty years, no research studies about the brain were published. Then, in 1985, an article by Marian Diamond of the University of California at Berkeley appeared in *Experimental Neurology*. She reported that Einstein's brain had an above-average number of glial cells (which nourish neurons) in those areas of the left hemisphere that are thought to control mathematical and linguistic skills and synthesize information from other parts of the brain. Other scientists discredited the research for not having compared the brain with enough other samples of brains of the same age as Einstein's.

In June 1999, Sandra Witelson, a neuroscientist at McMaster University in Ontario, Canada, published her research results on the brain in the British medical journal *Lancet*. Dr. Harvey had given her lab a section of the brain in 1996. The researchers compared Einstein's brain with the preserved brains of thirty-five men and fifty-six women known to have normal intelligence when they died. They discovered that in Einstein's case, the part of the brain thought to be related to mathematical reasoning—the inferior parietal lobe—was 15 percent wider than normal on both sides. Furthermore, they found that the Sylvian fissure, the groove that normally runs from the front of the brain to the back, did not extend all the way in Einstein's case. Witelson theorized that this latter feature may be the key to Einstein's intelligence, because the absence of a full groove may have allowed more neurons in this area to establish connections among one another and work together more easily. Other parts of Einstein's brain appeared to be somewhat smaller than average, putting overall brain size and weight within a normal range. Studies published in November 2012 (by D. Falk et al.) and September 2013 (by W. Men et al.) in the journal *Brain* discuss, respectively, the cerebral cortex and the corpus callosum. The overall size of the brain appeared normal to these researchers as well, but parts of the cerebral hemispheres had more extensive connections than the average brain and were deemed "extraordinary."

The most recent study as of this writing was conducted by psychologist Terence Hines of Pace University. He published his findings as "Neuromythology of Einstein's Brain" in *Brain Cognition* 88 (July 2014). He reviewed three earlier studies, whose conclusions he did not find convincing, writing that "the three histological studies of Einstein's brain have, in spite of claims to the contrary, found essentially no differences between his brain and that of controls.... The brain is obviously an *extremely* complex structure [and] to believe that the analyses of one or a few tiny slices of a single brain could reveal anything related to the specific cognitive abilities of that brain is naive." He suggested tests that could be undertaken. Neuroscientists appear to agree that we will never know definitively what precisely caused Einstein—and others—to be more intelligent than most of us.

Last Will and Testament

Before writing his final will as transcribed below, Einstein had written earlier ones at least in July 1923 and March 1925 (and perhaps later, as changing conditions required), which became obsolete. In these wills, he had bequeathed all his possessions, except the furnishings in his study, and financial assets to Elsa Einstein or to her daughters if she predeceased them. His sons, Hans Albert and Eduard, were to receive the contents of his study and the scientific books located in other parts of the apartment. (They and Mileva had already received the substantial Nobel Prize proceeds, with which they were able to buy income-producing property.) The books the boys did not want were to go to the Hebrew University Library in Jerusalem. While not mentioned in the terms of the early wills, Einstein also took care to provide for the sons, especially Eduard's medical expenses. (See Einstein Archives 29-126, 29-177.)

Last Will and Testament of Albert Einstein, March 18, 1950

IN THE NAME OF GOD, AMEN:

I, ALBERT EINSTEIN, of Princeton, New Jersey, being of sound and disposing mind and memory, and mindful of the uncertainty of life and the certainty of death, do hereby make, publish and declare this to be my Last Will and Testament, in manner following, to wit:

FIRST:

I direct that all my just debts and funeral and testamentary expenses be paid as soon as practicable after my decease.

SECOND:

I give and bequeath all of my furniture and household goods, chattels and effects, of every kind or nature, to my step-daughter, MARGOT EINSTEIN.

THIRD:

I give and bequeath my books and all of my personal clothing and personal effects, except my violin, to my secretary, HELENA DUKAS.

FOURTH:

I give and bequeath my violin to my grandson, BERNHARD CAESAR EINSTEIN. If he shall be not of legal age, then I authorize and empower my Executors to deliver the same to his father, my son ALBERT EINSTEIN, JR., in his behalf, to be turned over to my said grandson when he shall attain majority.

FIFTH:

I give and bequeath to my step-daughter, MARGOT EINSTEIN, the sum of TWENTY THOUSAND DOLLARS (\$20,000.00).

SIXTH:

I give and bequeath to my secretary, HELENA DUKAS, the sum of TWENTY THOUSAND DOLLARS (\$20,000.00).

SEVENTH:

I give and bequeath to my son, EDUARD EINSTEIN, the sum of FIFTEEN THOUSAND DOLLARS (\$15,000.00).

EIGHTH:

I give and bequeath to my son, ALBERT EINSTEIN, JR., the sum of TEN THOUSAND DOLLARS (\$10,000.00). If he shall predecease me, then I give and bequeath the said sum to my grandson, BERNHARD CAESAR EINSTEIN.

NINTH:

If my sister, MARIE WINTELER, shall be living at my death, I give and bequeath the sum of TEN THOUSAND DOLLARS (\$10,000.00) to my step-daughter, MARGOT EINSTEIN,

IN TRUST, NEVERTHELESS, to hold, invest and reinvest the same, and to pay over or to apply for the use and benefit of my said sister the income and principal thereof, to the extent and in the manner which my said step-daughter shall deem proper, for the care, comfort and welfare of my said sister, for life. If my said sister shall survive me but shall die before said fund shall be exhausted, then the balance of income and principal remaining at her death shall pass and be paid over by my said step-daughter, MARGOT EINSTEIN, to herself, for her own use and benefit. If my said step-daughter shall die or for any other reason fail or cease to act as Trustee of this fund, then I designate my secretary, HELENA DUKAS, as substitute in her stead.

TENTH:

If any of the legatees hereinbefore named shall predecease me, the bequest, legacy or fund provided for his or her benefit shall lapse, except as otherwise specifically hereinbefore provided, and the property or fund in question shall pass as part of my residuary estate.

ELEVENTH:

If the amount of my estate shall be inadequate to provide for the payment or setting up, in full, of the legacies and trust fund provided for in paragraphs FIFTH through NINTH hereof, then there shall be no priority, but the same shall abate proportionately.

TWELFTH:

After the foregoing legacies, bequests and trust fund shall have been paid, delivered or set up, and out of my then remaining estate, other than the specific property allocated by me to the trust fund next hereinafter provided

for, I direct my Executor to pay all transfer, estate or inheritance taxes which might otherwise be chargeable or apportionable upon or with respect to the foregoing bequests, legacies and trust fund, to the end that if the amount of my estate shall permit, the same shall be paid, delivered or set up in full as hereinbefore directed.

THIRTEENTH:

I give and bequeath all of my manuscripts, copyrights, publication rights, royalties and royalty agreements, and all other literary property and rights, of any and every kind or nature whatsoever, to my Trustees hereinafter named, IN TRUST, NEVERTHELESS, to hold the same for a term measured by the lives of my secretary, HELENA DUKAS, and my step-daughter, MARGOT EINSTEIN, and during such term to administer the said trust in manner following, to wit:

- (A) To sell, publish, license or otherwise dispose of any or all of the said property and rights so bequeathed to them as Trustees as aforesaid, and also any and all property received in exchange therefor, and any investments or reinvestments at any time held in this trust fund, in such manner, and upon such terms and conditions, as they, in their sole and absolute judgment and discretion, shall jointly determine from time to time.
- (B) To pay and turn over to my secretary, HELENA DUKAS, all of the net income received or collected from time to time, and as well any sum or sums of money whatsoever which shall constitute principal of this trust fund, and which may be received, collected or held hereunder by my Trustees, at any time or from time to time, all to the extent and in the manner to be solely determined by the said HELENA DUKAS in her own absolute discretion, and which may be required by her, during her lifetime, in writing delivered to the Trustees then acting hereunder, other than herself if she shall then be one of the Trustees.
- (C) After the death of the said HELENA DUKAS, to pay and turn over all such net income to my said step-daughter, MARGOT EINSTEIN, and similarly to pay and turn over to her any sum or sums of money out of the principal thereof to the same extent and in the same manner as provided in the foregoing subdivision (B) hereof.
- (D) To deliver and turn over to HEBREW UNIVERSITY any funds or specific property held in this trust, at any time, upon the written direction of the said HELENA DUKAS during her lifetime, and thereafter upon the written direction of my said step-daughter, MARGOT EINSTEIN, during her lifetime.
- (E) Upon the death of the said HELENA DUKAS and the said MARGOT EINSTEIN, this trust shall terminate, and thereupon all funds or property, if any, still held in this trust, including all accrued, accumulated and undistributed income and all literary rights and property, shall pass and be distributed to HEBREW UNIVERSITY, subject only to the expense and liabilities of the trust.
- (F) In the interpretation of this provision of my will, it is to be borne in mind that my primary object is to make further provision for the care, comfort and welfare of my said secretary, HELENA DUKAS, during her lifetime; my secondary object is to make such further provisions for the care, comfort and welfare of my said step-daughter, MARGOT EINSTEIN, during her lifetime; and my final object is that any such property which may then remain (whether it consist of original manuscripts, or literary rights or property still owned by my estate, or the proceeds from the disposition of any such property or rights) shall, to the extent that the same shall not have been distributed or paid over to my said secretary and my said step-daughter, pass to HEBREW UNIVERSITY and become its property absolutely, to be thereafter retained or disposed of by it as it may deem to be in its best interests. To these ends, I direct that if the said HELENA DUKAS, during her lifetime, or the said MARGOT EINSTEIN thereafter, shall require that any moneys be paid to them out of this trust, and there shall be inadequate funds available for the purpose, then property or assets of the trust shall be

sold or otherwise dealt with as may be necessary to produce such funds, but the Trustees of this fund shall jointly determine what shall be sold or otherwise disposed of, and the time, terms and manner of such sale or other disposition, and no such disposition may be made except upon such joint consent.

FOURTEENTH:

All of the rest, residue and remainder of my estate, of every kind or nature, whether real or personal, and wherever situate, I give, devise and bequeath to my step-daughter, MARGOT EINSTEIN, or if she shall predecease me then to my son, ALBERT EINSTEIN, JR., for her or his own use and benefit.

FIFTEENTH:

Without limitation of the absolute nature of the bequest of my residuary estate, if my sister, MARIE WINTELER, shall survive me and the trust fund for her benefit under paragraph NINTH hereof shall be thereafter exhausted, then I request my said step-daughter, or if she shall predecease me, then my said son, to make other or further provision, as may be necessary from time to time, out of my residuary estate to be received by them as aforesaid, for the care, comfort and welfare of my said sister, as long as she shall live.

SIXTEENTH:

I direct that there shall be apportioned to and charged against the trust fund under paragraph THIRTEENTH hereof that proportion of all federal or state transfer, estate, or inheritance taxes imposed upon my estate which the value of the property allocated to said trust shall bear to the amount of my net taxable estate before exemptions, all such values to be taken as they shall be determined in the respective tax proceedings. The amount of such taxes to be apportioned against such fund shall be a charge thereon, and the assets and property allocated thereto hereunder may be sold or otherwise disposed of either by my Executor alone, or by the Trustees of said fund, as may be necessary to provide funds to meet such taxes.

SEVENTEENTH:

- (A) I nominate, constitute and appoint my friend, DR. OTTO NATHAN, as sole executor hereof.
- (B) I further nominate, constitute and appoint the said OTTO NATHAN and my secretary, HELENA DUKAS, jointly, as trustees of the trust under paragraph THIRTEENTH hereof.
- (C) I further nominate, constitute and appoint my attorney, DAVID J. LEVY, ESQ., of the Borough of Manhattan, New York City, as substitute executor hereof, and substitute trustee of the trust under paragraph THIRTEENTH hereof.
- (D) I direct that my said executor, trustees and substitute shall be permitted to qualify and act hereunder, at any time and in any jurisdiction, without giving bond or other surety.

EIGHTEENTH:

I do hereby confer upon my executor, trustees, and any substitute, the power, authority and discretion, without application to any court, and in addition to the rights and powers otherwise provided by law: (1) To hold and retain any assets or property received hereunder, and any property received in exchange therefor, either permanently or temporarily, as they in their sole judgment and uncontrolled discretion shall determine; (2) to sell, exchange or otherwise dispose of same, either for cash or upon credit, secured or unsecured; (3) to mortgage, lease or sell any and all real estate on any terms and conditions; (4) to grant options, and to participate, as to assets or property held by them, in any reorganizations or rearrangements, upon any terms; (5) to borrow money, without personal liability, and upon any terms and conditions deemed advisable, and to secure repayment thereof; (6) to adjust, compromise or arbitrate any claims or demands of or against my estate, including tax matters; (7) to hold securities or property of my estate in the names of nominees, or in such form as to pass by delivery; (8) to maintain a custody account or accounts, and to employ investment counsel or accounting services, charging the cost thereof to my estate; (9) to make distributions either wholly or partly in kind, and for that purpose to fix

values; (10) to determine and allocate income and principal and charges thereto; (11) to pay or apply income or principal for any minor beneficiary hereunder either directly to such beneficiary or to his parent or legal or natural guardian, or to any person standing in loco parentis or otherwise; and (12) to do, generally, any and all things with respect to my estate as they in their good judgment shall deem wise and proper and in the best interests of the beneficiaries hereof, it being my intention that all of the foregoing shall be construed so as to give my said executor, trustees and substitute the broadest and widest latitude in the administration and management of my estate, so long as they shall act in good faith.

LASTLY:

I hereby revoke any and all wills or codicils by me at any time heretofore made.

IN WITNESS WHEREOF, I have hereunto set my hand and seal, this 18th day of March, in the year one thousand nine hundred and fifty. *ALBERT EINSTEIN (L.S.)*

SIGNED, SEALED, PUBLISHED and DECLARED by ALBERT EINSTEIN, the Testator above-named, to be his Last Will and Testament, in our presence, and we, at his request, and in his presence, and in the presence of each other, have hereunto subscribed our names as witnesses, this 18th day of March, 1950.

KATHERINE RUSSELL, Residing at Winant Road, Princeton, N.J.

KURT GÖDEL, Residing at 129 Linden Lane, Princeton, N.J.

DAVID J. LEVY, Residing at 1092 East 21st St., Brooklyn, N.Y.

Part II

A Life in Science

Annus Mirabilis

(See discussion of all 1905 papers in [appendix C](#).)

During his “year of miracles” in 1905, Einstein produced and published five remarkable papers. The year proceeded as follows.

On March 17, he finished writing “On a Heuristic Point of View concerning the Production and Transformation of Light,” which boldly employs the quantum hypothesis to explain the photoelectric effect in metals (published June 9 and cited in his Nobel Prize award). This was the only one of the five papers that Einstein regarded as truly revolutionary.

On April 30, he completed his doctoral dissertation, “A New Determination of Molecular Dimensions,” in which he created a new method of determining molecular sizes and Avogadro’s number (published in a slightly different version in August, shortly before he officially received his doctorate).

In May, he finished “On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat,” his first paper on Brownian motion, leading to experiments validating the kinetic-molecular theory of heat and the atomic hypothesis in physics (published on July 18).

In June, he finished “On the Electrodynamics of Moving Bodies,” his first paper on the special theory of relativity and a landmark in the development of modern physics (published September 26).

In September, he completed “Does the Inertia of a Body Depend upon Its Energy Content?” in which he maintained that inertial mass is associated with all forms of energy because of the relativity principle (published November 21). It is this paper that first proposed the generality of the famous equation $E = mc^2$.

Assistants

Einstein did not have research students in the usual sense, nor did he found a research school. In the early years of his career, he worked in almost complete isolation, but after becoming a professor for the first time in 1909, he did work with a few young research assistants, and from 1928 on he availed himself of research help from a series of younger assistants. Their position with Einstein was akin to that of a modern postdoctoral researcher. Einstein’s interest in having research assistants seems to correspond with the period of his life in which he worked primarily on a unified field theory of gravity and electromagnetism. Just as he had engaged in a fruitful collaboration with his longtime friend, the mathematician Marcel Grossmann, while working on the development of what would become general relativity, so he felt the need for a collaborator in the mathematically intensive task of searching for a unified field theory. More details on this are available in Pais’s biography of Einstein, “*Subtle Is the Lord*,” which is the main source for this section.

Ludwig Hopf was Einstein’s first assistant, joining him at his first academic job at the University of Zurich. With Einstein, he wrote papers on the statistical aspects of classical radiation theory. He moved with Einstein to the German University in Prague in 1912, where he was succeeded by *Emil Nohel*, a young mathematician. Nohel and Einstein did not produce any publications together before Einstein’s return to Switzerland. Nohel and his family were murdered in the Nazi death camps during

the Holocaust.

Einstein's third assistant, *Otto Stern*, began working with Einstein in Prague and then moved with him back to Zurich. They produced a paper on specific heat of low-temperature gases, an attempt to address a problem that Einstein would later solve completely as a result of the work of the Indian physicist Satyendra Bose. Nevertheless, the paper is a landmark in that it was the first to introduce the concept of zero-point energy. Einstein and Stern observed that in many quantum states the lowest energy state available (the ground state) contains energy. Thus, there is a minimum amount of energy that can never be extracted from the system, the zero-point energy. Stern then left Einstein for Frankfurt, where he performed his seminal experiments with Walter Gerlach. They proved the existence of half-integral electron spin (related to one of the few experimental topics on which Einstein, together with Wander de Haas, had worked extensively; see Collaborators, "Wander de Haas"). In 1944, he was awarded the 1943 Nobel Prize for this work, though his award does not speak of the Stern-Gerlach experiment itself, since the prize was given only to Stern, a Jewish refugee from Nazi Germany, and not to Gerlach, who had collaborated with the Nazis.

After Stern, Einstein had no other assistants funded by a university through what might be considered the usual process. In 1914, he moved to Berlin to take a position in the Prussian Academy of Sciences and worked alone for a number of years, even after assuming the directorship of his own research institute of the Kaiser Wilhelm Society in 1917. But from the beginnings of his work on a unified field theory in the mid-1920s, Einstein seemed to require the help of younger men (and one woman). The first of these assistants was *Jakob Grommer*, who worked with Einstein for several years in the mid-twenties. Grommer was unable to obtain any kind of academic position, handicapped by his Russian-Jewish origin and by physical deformity (he suffered from a disease that produced enlarged features of his head and limbs). Having been educated as a Talmudic scholar in his native White Russia (today's Belarus), he went to Göttingen to study mathematics and was quickly recognized as a prodigious talent. He worked with Einstein for years, supported by the Kaiser Wilhelm Institute for Physics, of which Einstein was the director, before obtaining an academic position in Minsk, Belarus. He died tragically young in 1933.

Perhaps encouraged by the experience of working with Grommer, Einstein obtained more formal funding for future assistants from the Emergency Association of German Science (Notgemeinschaft der Deutschen Wissenschaft), an organization set up in 1920 to obtain funds for German scientific research from public and private sources. When he moved to America, his assistants were funded primarily by the Institute for Advanced Study in Princeton.

The first to hold one of the more formal Notgemeinschaft positions was *Cornelius Lanczos*, a Hungarian physicist who became Einstein's assistant in 1928. He was not, however, particularly attracted by Einstein's ideas on the unified field (at that time Einstein was working on the teleparallelism approach), and they did not produce any joint papers.

Overlapping with Lanczos was *Hermann Muentz*, who worked with Einstein on the teleparallelism theory. In 1930, Einstein began a lengthy period of collaboration with *Walther Mayer*, for whom he found a series of positions, including a permanent one at the Institute for Advanced Study in Princeton when Einstein went there in 1933. They worked together on the teleparallelism theory and on semivectors. Ironically, shortly after both men were settled in Princeton, the collaboration ended and Mayer concentrated on his own research in pure mathematics.

Einstein's first American assistant was *Nathan Rosen*, who worked with him from 1934 until 1936, when he departed to accept a position in the Soviet Union. He and Einstein collaborated on three noteworthy papers: the famous Einstein-Podolsky-Rosen paper; a paper on what is known as the Einstein-Rosen bridge (also known as a wormhole); and a paper on gravitational waves that originally tried to show that these waves did not exist in the exact theory of general relativity, but ultimately presented one of the first exact solutions for gravitational waves within the theory.

After Rosen's departure, Einstein worked from 1936 to 1938 with *Leopold Infeld*, a Polish Jew who was older than most of Einstein's assistants and had been unable to obtain a permanent position in Europe because of anti-Semitism. Einstein's friend Max Born had recommended him. Infeld, together with a younger assistant, *Banesh Hoffmann*, worked on the problem of motion in general relativity (their paper on this

topic is often known as EIH, representing the initials of its authors). When Infeld's funding at the Institute for Advanced Study was not renewed, he and Einstein collaborated together on a popular book on science, *The Evolution of Physics* (1938; see no. 164 in [appendix C](#)), the proceeds of which funded Infeld for another year. From 1938 to 1950, Infeld worked at the University of Toronto. Infeld was a socialist and a victim of the postwar red scares, and when prominent Canadian politicians and newspapers falsely accused him of dispensing secret atom bomb information to the Soviet Union, he returned to Poland in 1950, where he died in 1968. (See also Infeld, *Quest*, and Einstein and Infeld, *Evolution of Physics*.)

Also overlapping with Infeld's tenure was *Peter Bergmann*, another European refugee. He had obtained his doctorate working in Prague with Einstein's successor there, Philipp Frank, and Frank had recommended him to Einstein (Einstein and Frank were friends, and Frank later wrote a well-known biography of Einstein (see [appendix A](#)). Bergmann, Infeld, and Rosen are notable for founding major schools of relativity in the postwar period, helping to spark the renaissance of general relativity (Bergmann at Syracuse, New York; Infeld in Warsaw, Poland; and Rosen at the Technion in Haifa, Israel). Their students, especially Bergmann's, played a leading role in the "golden age of relativity" in the 1960s and '70s.

Later assistants who worked with Einstein from around 1940 until his death in 1955 included *Valentin Bargmann*, who was subsequently known for his work with Eugene Wigner on quantum mechanics; *Ernst Straus*, who later became a leading mathematician; *John Kemeny*, a computer scientist known as one of the developers of the BASIC programming language; *Robert Kraichnan*, later known for his work on the physics of turbulence in fluids; and *Bruria Kaufman*, Einstein's only female assistant or collaborator.

Collaborators

Einstein is known for the paucity of his collaborators. Apart from Marcel Grossmann, there is no scientist who coauthored a paper dealing with one of Einstein's major scientific discoveries. In his early years especially, he worked in great isolation from other physicists. In his later years, despite worldwide fame, he managed to achieve an isolation that, while not comparable to the early years, was remarkable under the circumstances. In those years, he collaborated almost exclusively with his assistants.

Nevertheless, between his emergence from his early isolation, around 1907, and his late period, from the mid-1930s on, he managed to have a significant number of collaborators. These collaborations reflect the wide range of his scientific interests and the fact that he was, especially in his middle years, a more sociable person than is often surmised. Apart from his unusual "collaboration" with the Indian physicist Satyendra Nath Bose (discussed below), these joint efforts did not generally touch on the most profound topics in which he was interested, but more often reflected his interest in technical matters or scientific sidelights. A number of the collaborations resulted in patents rather than published papers in pure research.

In discussing the collaborators with whom Einstein published jointly, we also attempt to give a sense of the numerous collaborations that resulted in separate but linked publications (examples include Satyendra Bose, Gunnar Nordström, and Emil Rupp); contributions and suggestions from amateurs whose work Einstein acknowledged in his papers (Michele Besso—see [Part I](#), Friends—and Rudi W. Mandl); and collaborations that produced only negative or null results and did not lead to publications (Auguste Piccard). These collaborations exemplify Einstein's widespread scientific contacts during the middle part of his scientific career. They are not, however, included in the table on page 145, which is restricted to collaborations that led to published papers with Einstein's coauthors and assistants. Most of these informal "collaborators" interacted with Einstein more through correspondence than in person.

Einstein's first collaborators were fellow physicists from the southern reaches of the German-speaking world. *Jakob Laub* was an Austrian physicist and an early researcher on special relativity with whom Einstein, at Laub's prompting, produced two papers. *Walter Ritz* was a Swiss colleague of Einstein's who had his own views on the correct formulation of electrodynamic theory. They shared an interest in the emission theory of light. He and Einstein tried to collaborate but ended up publishing

a brief statement of their disagreement in 1908. The paper discussed the interesting fact that the retarded potential solutions to electrodynamic equations are routinely observed in real life, while the mathematically equally valid advanced potentials (in which receivers respond to radiation before it is emitted at the source) are never observed in nature. In the paper, Ritz stated that he thought the equations of electrodynamics needed reformulation so that the advanced potentials were no longer solutions of the equations. Einstein, contrarily, stated his belief that the retarded solutions are seen entirely because there are a large number of interacting particles in the universe and the advanced potentials disappear on probabilistic grounds. This is a technical way of stating that the arrow of time (*see* Concepts) in electrodynamics (the fact that the Sun is losing energy over time due to radiation and not gaining it) arises, as it does in thermodynamics, because it is the overwhelmingly likely result in a universe made of many interacting particles. An example of a later theory that puts Einstein's ideas into mathematical form is the absorber theory of John Wheeler and Richard Feynman. Wheeler, Einstein's colleague at Princeton, reported the results to Einstein, who, according to Wheeler's autobiography, approved of them.

An early example of his technical collaborations is his work with the *Habicht brothers, Conrad and Paul*. The first was a close friend of Einstein's during his Bern years (and a member of the Olympia Academy; *see* Part III, Organizational Ties); his younger brother, Paul, was a technical designer in Basel and later, privately, in his hometown of Schaffhausen. Around 1907, Einstein began work on his *Maschinchen* (little machine) (*fig. 36a, b*), a device designed to use a series of capacitors to perform electric amplification of small voltages that took advantage of voltage fluctuations in the capacitors. The idea arose out of Einstein's mastery and development of fluctuation theory, the origin of many of his early scientific breakthroughs. For a number of years, Paul Habicht, in particular, tried to realize Einstein's invention, but the project was eclipsed by other, more successful technologies and never led to a patent. One *Maschinchen* is on display at the Physics Institute of the University of Tübingen, another in the Museum Boerhaave in Leyden, the Netherlands.

Einstein's vital collaboration with his friend *Marcel Grossmann* in developing the so-called outline (or *Entwurf*) theory of gravity that preceded general relativity is discussed under the section on Grossmann in Part I, Friends. Though he was never a coauthor with Einstein, the mathematician *David Hilbert* (*see also* Colleagues) played a key role in encouraging Einstein to move beyond the version of the theory he had developed with Grossmann and to resume the quest for the fully covariant theory he had originally envisioned. The astronomer *Erwin Finlay Freundlich* was encouraged and supported by Einstein in his efforts to find experimental verification of general relativity theory, as were two German experimentalists, *Leonhard Grebe* and *Albert Bachem*. (For the contributions of all three men, *see* Relativity Theory, "General Relativity—Experimental Tests of General Relativity.")

Adriaan Fokker was a Dutch theoretical physicist who worked with Einstein in Zurich in 1913–1914. Their collaboration focused on the gravitational theory of Gunnar Nordström, a Finnish theorist also based in the Netherlands. Although Nordström never published with Einstein on this theory, we know from their correspondence that Einstein played an influential role in its development, and it was put into the form in which it is best known in the paper by Einstein and Fokker. Nordström's theory began as a fairly conventional attempt to incorporate gravitational theory into the framework of special relativity. Ironically, as a result of his discussions with Einstein, and the work of Einstein and Fokker, his theory became the first metric theory of gravity, predating even general relativity itself, which was not formalized until late 1915. Fokker later consulted with Einstein on his efforts to establish a correct understanding of what is now termed geodetic precession, an effect of Einstein's theory of gravity that emerged from the work of Dutch scientists Willem de Sitter and Jan Schouten.

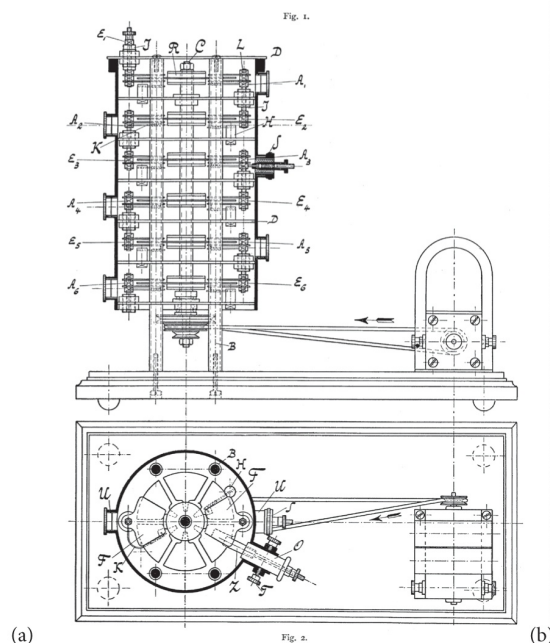


FIGURE 36. (a) The “Maschinchen” (little machine) developed with the Habicht brothers. (Photo by and courtesy of Torsten Hehl, University of Tübingen) (b) Schematic of the machine, as depicted in an article in *Physikalische Zeitschrift*, no. 11 (1910). (Courtesy of University of Tübingen)

Wander de Haas was another Dutch colleague of Einstein’s during the time when Einstein regularly traveled to the Netherlands to meet with colleagues there, especially Paul Ehrenfest, another collaborator from this period (see [Part I](#), Friends). De Haas was H. A. Lorentz’s son-in-law, and Einstein was able to arrange a visiting position for him in Berlin at Lorentz’s request. In one of Einstein’s occasional excursions into experimental physics, they worked on a series of experiments investigating the molecular current hypothesis of André-Marie Ampère. Since it was known that electric currents produce magnetic fields, Ampère proposed that ferromagnetic substances most likely exhibited magnetic properties because of charged particles within them that moved in some kind of closed circuit. In order to test this hypothesis, Einstein and De Haas showed that ferromagnets behaved like gyrocompasses, suggesting that they did indeed have some kind of orbiting or rotating physical bodies inside them. Their experimental discovery is known as the Einstein-de Haas effect, which states that magnetizing a material can induce a measurable mechanical rotation in it. This demonstrates the connection between physical rotation in the material and the production of its magnetic field.

Einstein’s calculations assumed that electrons were responsible for the current loops and that they made simple rotations and orbits. He thus introduced into his calculations a gyromagnetic factor that he naturally assumed to be 1. The experimental results he obtained agreed with this result, but subsequent experiments by others disagreed, obtaining values closer to 2. Eventually, it was understood that the property of the electron that produces ferromagnetism is not an orbital motion but an intrinsic property of the electron called “electron spin.” It turns out that the spin of the electron always has a half-integer value (thought to be impossible in classical physics) that produces a gyromagnetic factor of 2. Thus, Einstein and de Haas’s experiments were qualitatively right—and of considerable importance both scientifically and from a technological point of view—but were numerically wrong, and Einstein had managed to get the experimental results to agree with his own erroneous theoretical calculations. This experiment is often cited as a significant example of the predictor effect in science.

The experiment that did the most to clarify the origin of the Einstein-de Haas effect was the discovery of electron spin by *Otto Stern* and *Walter Gerlach*. Stern was, coincidentally, another of Einstein's collaborators, having worked as his assistant on unrelated matters.

Hermann Anschütz-Kaempfe was a German industrialist and explorer who wished to reach the North Pole by submarine. Because submarines are entirely surrounded by metal, the Earth's magnetic field cannot penetrate to the interior of the vessel and thus magnetic compasses cannot work, an especially serious handicap in trying to find the North Pole while under water. Anschütz-Kaempfe's company developed a practical gyrocompass for onboard navigation on submarines and aircraft. Conservation of momentum causes spinning gyroscopes to maintain their pointing even as the platform on which they rest moves around. In an effort to enforce his patents in America, Anschütz-Kaempfe hired Einstein as a technical expert in a patent suit. Einstein, with his scientific prestige and his background in patent work, was sometimes solicited as a technical expert in such cases. Einstein was intrigued by the challenges of designing a successful gyroscopic compass, and he worked for the company intermittently over a number years on various aspects of the design, frequently visiting the firm at its headquarters in Kiel. He and Anschütz-Kaempfe became quite close, and he often visited the industrialist's home, sometimes with his sons. As a result of this work, Einstein played a role in a later patent for the gyroscope. The Anschütz company continues to manufacture navigational equipment in Germany, now as a division of the Raytheon corporation. This collaboration was one of many on work that led to patents; only a few of them are mentioned here because of Einstein's personal closeness to the collaborators. Interested readers should consult József Illy's book *The Practical Einstein*, which was our major source for Einstein's patents.

In 1924, Einstein received a letter from *Satyendra Nath Bose*, an Indian physicist who was having difficulty publishing his paper on a new derivation of the Planck law for blackbody radiation. Remarkably, Einstein not only read the enclosed paper by an unknown scientist from far away, but did so closely enough to spot the key feature that it performed a statistical analysis of an ensemble of particles while assuming that none of the particles were distinguishable from one another. Even Bose himself was not sufficiently aware of this feature to have drawn proper attention to it. This is an important difference from classical statistical physics, where one always presumes that it is possible to keep track of each individual particle and what it is doing if so desired. Bose's approach assumed that one would have no idea which particle was doing what, that all would look alike and be impossible to trace individually. The fact that, by making this assumption, Bose was able to derive Planck's result from first principles suggested that this was the correct way to do the statistics of quantum particles.

Einstein saw to it that the paper was published, and he wrote a series of papers brilliantly exploiting this breakthrough discovery (see "Bose-Einstein Condensate" and "Bose-Einstein Statistics" under Concepts). Although the names Bose and Einstein never appeared together on a paper, and though they did not personally meet during the collaboration, it can be fairly stated that this was the most important collaboration of Einstein's life, besides his work with Marcel Grossmann. Abraham Pais has commented on the fact that the work of Einstein and Bose in founding quantum statistics was sufficient to immortalize Bose's name forever, yet this collaboration does not even count among Einstein's five principal contributions to science.

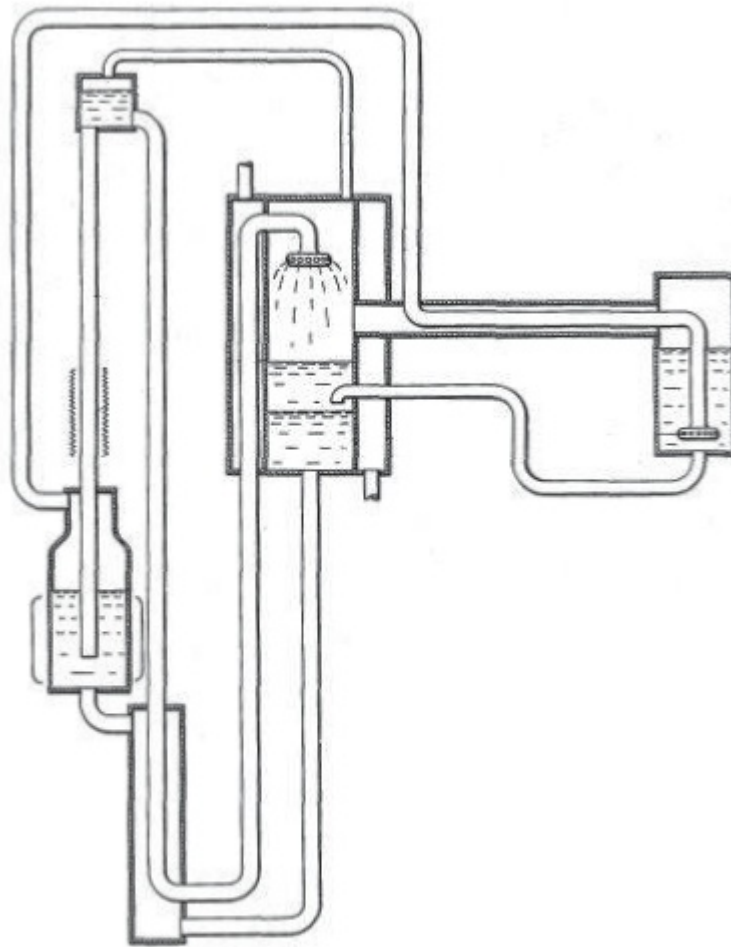
An ultimately less happy collaboration was that with *Emil Rupp*, a young German physicist who performed experiments with canal rays (see Concepts) designed by Einstein in order to test the quantum properties of light. The two men published separate but simultaneous papers reporting the results. Rupp's work, based on Einstein's ideas, was challenged by fellow experimenters. Years later, after being found guilty of fabricating results of experiments he never actually performed, he was forced to leave physics in disgrace.

Another experiment inspired by Einstein was conducted by the Swiss-Belgian physicist *Auguste Piccard* in Brussels in response to a theoretical speculation by Einstein that the Earth's magnetic field could be explained if there were an imbalance between the attractive and repulsive forces produced by electric charges. Piccard performed very sensitive experiments, with suggestions from Einstein, to show that no

such imbalance existed. In this case, Einstein was acknowledged in Piccard's publication but never published himself because of the null result. Piccard, a well-known figure for setting records in ballooning and deep-sea exploring, was the inspiration for the character of Professor Calculus, drawn by Belgian cartoonist Hergé (Georges Remi) in his comic strip, *The Adventures of Tintin*.

Einstein enjoyed collaborations with friends, including *Paul Ehrenfest* and *Hans Mühsam* (see [Part I](#), Friends, for both), a doctor at the Jewish hospital in Berlin and one of his closest friends during his years in that city. Einstein and Mühsam collaborated on an experiment to measure the permeability of filters to microscopic particles suspended in fluids.

Of an even more practical nature was the research in which Einstein engaged with *Leo Szilard*. The two physicists aimed to invent a noiseless method of refrigeration (the pumps in refrigerators of the 1920s were very noisy) ([fig. 37](#)). Although the idea showed promise, it did not prove to be commercially successful, but it did have applications in the laboratory. Szilard and Einstein were awarded a number of patents for their inventions in this area. Szilard later became famous as the proposer of the idea of a nuclear chain reaction and, with Enrico Fermi, was the first to demonstrate its practicality using nuclear fission. He played a key role in the origins of Allied attempts to construct an atomic bomb (see [Part III](#), Political Contexts, “Hitler in Power and the Second World War—Letters to FDR”).



Einstein Refrigerator

Patent number US1781541 -- November 11, 1930

*Albert Einstein
Leo Szilard*

FIGURE 37. An Einstein-Szilard refrigerator patent. (Wikimedia Commons)

Rudolf Goldschmidt, a successful inventor in the field of radio, collaborated with Einstein in the invention of a magnetostrictive sound reproduction device for a new type of hearing aid. Einstein became interested in this project, according to his biographer Abraham Pais, when a friend of his, who was a singer, became hard of hearing. (See Illy, *The Practical Einstein*, pp. 127–130, for the authoritative account.) Einstein enlisted Goldschmidt's aid in trying to help the singer and even composed a verse to mark their collaboration. Goldschmidt had worked in England before the First World War and returned there after the Nazi seizure of power.

Richard Chase Tolman was a physical chemist who played a leading role in the rise to prominence of the California Institute of Technology. Einstein spent three successive winter semesters there in the early 1930s, during which time he worked on a paper with Tolman and another collaborator, *Boris Podolsky* (see below). The paper concerned the problem of measurement in quantum mechanics, an issue to which Einstein and Podolsky would later return. Tolman was one of the early American

adopters of relativity theory and made important contributions to the emerging field of cosmology. During his time at Caltech, Einstein also collaborated with the astronomer *Willem de Sitter* on a paper on cosmology (see the section on de Sitter under Colleagues, below).

Boris Podolsky was a Russian immigrant to the United States who obtained his PhD at Caltech with Paul Epstein, whose work had earlier drawn Einstein's admiration. Epstein had served as doctoral thesis adviser to Einstein's cousin Edith and, in that capacity, corresponded regularly with Einstein on the subject of that thesis (suggested by Einstein), the radiometer problem (see Concepts, below). While at the Institute for Advanced Study in Princeton in 1934–1935, Podolsky worked with Einstein and his then assistant Nathan Rosen on the famous EPR paper (see Concepts). It has been claimed (for instance, by Pais, citing Rosen as the source) that Podolsky wrote the well-known paper.



FIGURE 38. An Einstein ring, in which a large red galaxy gravitationally lenses light from a distant blue galaxy into a characteristic shape predicted by Einstein in 1936. At the time, Einstein thought “there is no hope of observing this phenomenon directly” (*Science* 84 [1936]: 506), but he was thinking only of stars, where the Einstein ring would be too small to be visible as a ring. Galaxies are much more powerful gravitational lenses, and even a double Einstein ring (with two distant galaxies seen behind a foreground galaxy) has been observed. Gravitational lenses are vital tools of modern extragalactic astronomy, since they permit distant objects to be seen that would otherwise be undetectable, and they provide information about the mass of the lensing object that would otherwise be unobtainable. Lenses have helped convince astronomers of the existence of dark matter. (ESA/Hubble and NASA)

Einstein was extraordinarily open to good ideas regardless of the source, including scientific amateurs. In 1936, he was approached by an enthusiastic Czech émigré named *Rudi W. Mandl* who had independently come upon the idea of gravitational lensing, in which the light from a distant star is focused and intensified for astronomers on Earth by the gravitational field of a fortunately positioned nearer star. Einstein patiently tried to convince Mandl that the idea, which Einstein himself had come upon years earlier, was not practical, and he even performed the calculations to

prove it. Einstein did not wish to publish a non-result of this kind but eventually did due to the persistence of Mandl, who was acknowledged by name in the paper. Almost immediately, the astronomer Fritz Zwicky pointed out that the effect predicted by Einstein's formula ought to be detectable in galaxies. Decades later, this observation proved true, and gravitational lensing is now a major technique in galactic astronomy—and even, due to improvements in astronomical technology, in stellar astronomy. The ring of light produced by a perfectly aligned gravitational lens is still known as the Einstein ring (fig. 38).

Gustav Bucky was a German medical doctor specializing in radiology. He and Einstein knew each other from Germany and remained good friends after both had immigrated to the United States. Together they were awarded a patent for a photoelectric device that could make a camera respond to the object to be photographed. Bucky held a total of 148 registered patents at his death, though only about twelve were ever used for commercial purposes. He invented the Bucky diaphragm, which eliminated the dissipation of X-rays on contact, thereby making the X-raying of the human body more feasible. Bucky and his family, who had moved from Germany to New York, were among Einstein's closest friends in America.

In 1943, Einstein collaborated with his longtime colleague *Wolfgang Pauli* on a study of the structure of spacetime in general relativity and the five-dimensional Kaluza-Klein theory. Apart from this project with Pauli, his other collaborators in the 1940s and 1950s were, as previously stated, his assistants. (See also Galison, *How Experiments End*; Illy, *The Practical Einstein*; and van Dongen, "Emil Rupp, Albert Einstein.")

TABLE OF EINSTEIN'S COLLABORATORS

Name	Place	Years	Papers	Patents	Assistant
Jakob Laub	Bern	1908	2	0	
Walter Ritz	Bern, Zurich	1909	1	0	
Conrad Habicht	Bern, Zurich	1907–10	1	0	
Paul Habicht	Bern, Zurich	1907–10	1	0	
Ludwig Hopf	Zurich	1910	2	0	Yes
Emil Nohel	Prague	1911–12	0	0	Yes
Otto Stern	Prague, Zurich	1912–13	1	0	Yes
Marcel Grossmann	Zurich	1912–14	2	0	
Adriaan Fokker	Zurich	1913–14	1	0	
Wander de Haas	Berlin	1915	3	0	
Jakob Grommer	Berlin	1917–28	1	0	Yes
Hermann Anschütz-Kaempfe	Kiel	1918–26	0	1	
Paul Ehrenfest	Leyden	1922–23	2	0	
Hans Mühsam	Berlin	1923	1	0	
Leo Szilard	Berlin	1927–30	0	15	
Rudolf Goldschmidt	Berlin	1928–34	0	1	
Cornelius Lanczos	Berlin	1928–29	0	0	Yes
Hermann Muentz	Berlin	1928–29	0	0	Yes
Walther Mayer	Berlin, Princeton	1930–34	8	0	Yes
Richard Tolman	Pasadena	1931	1	0	
Willem de Sitter	Pasadena	1932	1	0	
Boris Podolsky	Pasadena, Princeton	1931/35	2	0	
Nathan Rosen	Princeton	1934–36	3	0	Yes
Gustav Bucky	Princeton	1936	0	1	
Leopold Infeld	Princeton	1936–41	3+1 book	0	Yes
Banesh Hoffmann	Princeton	1935–37	1	0	Yes
Peter Bergmann	Princeton	1936–41	2	0	Yes
Valentin Bargmann	Princeton	1937–44	2	0	Yes
Wolfgang Pauli	Princeton	1943	1	0	
Ernst Straus	Princeton	1944–48	2	0	Yes
John Kemeny	Princeton	1948–49	1	0	Yes
Robert Kraichnan	Princeton	1949–50	0	0	Yes
Bruria Kaufman	Princeton	1950–55	2	0	Yes

Colleagues

Friedrich (Fritz) Adler

Friedrich Adler (1879–1960) was an Austrian physicist and political activist and the son of Victor Adler, the founder of the Austrian Social Democratic Party. Although he and Einstein worked for the same doctoral adviser, Alfred Kleiner, they did not know each other as students. The younger Adler was an unsalaried physics instructor at the University of Zurich and a candidate for a professorship there in 1909. When he advised the authorities to give Einstein the nod instead, the official who interviewed him could scarcely believe that Adler would defer so graciously to a rival (see Friedrich Adler to Victor Adler, March 19, 1909; Einstein Archives 73-565). Einstein was hired, and the two men and their families ended up living in the same apartment building in Zurich. They became good friends.

When Einstein received the call to Prague, he hoped that Adler would succeed him at Zurich, but Adler turned to politics and subsequently devoted himself to radical socialist and pacifist politics. In 1916, he acquired great notoriety when he assassinated the minister-president of Austria, Count Karl von Stürgkh, to protest the prosecution of the Great War. Einstein offered to be a character witness on his behalf, also writing a letter to the Austrian-Hungarian emperor pleading for clemency on Adler's behalf, claiming that few had known Adler as well as he had. The international outcry in his favor saved him from the death sentence. Ironically, he used his time in prison to write an article and then a book opposing Einstein's relativity theory. Einstein referred to the manuscript of the book, which Adler sent him from prison, as "worthless pedantry, using the methods of an attorney to do physics" (see letter to Heinrich Zangger, May 4, 1917, in Schulmann, *Seelenverwandte*, Doc. 153). His father, both a leading politician and a noted psychiatrist, attempted to use his son's quixotic attempt to dethrone Einstein as evidence that he was insane for the purposes of mounting a legal defense. Freed after the war, he was involved in socialist politics throughout the interwar years. While giving an address to the Socialist International, he anecdotally bored some of the deputies, leading Léon Blum, a French politician, to remark to his neighbor; "He shoots better than he speaks." He and Einstein remained friends to the end of their lives.

Niels Bohr

Niels Bohr (1885–1962) was a Danish physicist who developed the Bohr model of the atom and played a leading role in the development of quantum theory. His name is forever linked with Einstein's in part because of their debate in the mid-1920s over quantum mechanics. Einstein first met Bohr in April 1920 and was immediately drawn to him: "Not often in life has a person given me such joy as you have by your mere presence" (see letter to Bohr, May 2, 1920, *CPAE*, Vol. 10, Doc. 4; Einstein Archives 8-065). The two men debated physics in a passionate yet cordial way while Einstein lived, and Abraham Pais has written that "even after [Einstein's] death, he [Bohr] would argue with him as if Einstein were still alive." The two men were linked also in the timing of their Nobel prizes. Bohr received his, for 1922, at the same time as Einstein received the deferred physics prize for 1921 (see Nobel Prize, *below*). They received the award for their development of a quantum theory that, with the rise of quantum mechanics, would very shortly become the central idea of twentieth-century physics. Bohr and Einstein represented a new generation of theoretical physicists who had previously stood in the shadow of the experimentalists. In terms of public recognition, theoreticians like Bohr would come to dominate the prize. When they received their Nobels, it would have been unthinkable to imagine that the two men would arrive at diametrically different positions in the debate on that theory, but their dispute is nevertheless remembered as a model of scientific collegiality (see Thought Experiments, *below*). During the war, Bohr was obliged to flee Denmark after the Nazi invasion, and, as with Einstein, this caused ruptures with some of his previously close colleagues in Germany. Afterwards he returned to his own country. He was noted for his ability as a scientific mentor, both to graduate students and postdocs, and his native Copenhagen remained a major center of physics until his death. The Copenhagen interpretation of quantum mechanics is, in some ways, the outcome of his debates with Einstein. (See also Pais, *Niels Bohr's Times*.)

Marie Curie

Marie Skłodowska-Curie (1867–1934) was a Polish-French physicist and one of the few scientists who has been awarded the Nobel Prize twice (once in chemistry and once in physics). She was perhaps the only twentieth-century scientist whose fame in any way rivaled Einstein's. Her work on the origin of radioactivity included the celebrated discovery of the element radium and another radioactive element, polonium. Her work on natural radioactivity had immediate and profound effects in astronomy, geology, chemistry, physics, and medicine, permitting scientists finally to answer, among other things, the long-standing question of the age of the Earth. She was instrumental in the emerging consensus of the atomistic worldview, a movement in which she and Einstein were leading figures. They were cordial colleagues, and in the period after the First World War, they corresponded and worked together in the

political sphere trying to facilitate postwar reconciliation among nations, particularly through the League of Nations (see [Part III](#), Organizational Ties, “International Committee on Intellectual Cooperation”).

Arthur Stanley Eddington

Arthur Stanley Eddington (1882–1944) was an English astrophysicist who helped make Einstein a world-renowned figure with his scientific and popular writings on relativity theory and because of his role in testing one of the most important predictions of general relativity. Eddington himself is one of the most important scientists in the rise of astrophysics as a subject, especially for his work on the structure of stars. He showed that stars do not collapse under their own weight because of the intense pressure of the enormous quantity of light that is generated in the stars’ cores by thermonuclear fusion. (It can take hundreds of thousands of years for one particle of light, a photon, to travel from the core of the Sun to its surface.) Eddington became aware of Einstein’s new theory of gravity in 1916, through the papers of Dutch astronomer Willem de Sitter. The intermediary was necessary not only because Eddington did not speak German, but because Germany and England were at war and German scientific journals were hard to come by in England. Eddington was quickly attracted to the theory and began to publish his own accounts of it, which caught the attention of English scientists. Eddington discussed the theory with Sir Frank Dyson, England’s Astronomer Royal. They realized that one of the three experimental tests of the theory proposed by Einstein was difficult to accomplish because it required observing stars close to the Sun during a total eclipse. Dyson observed that the solar eclipse of 1919 would be perfect for this test, because the Sun would be in the Hyades star cluster, the brightest collection of stars on the ecliptic. Accordingly Dyson and Eddington made plans to mount an expedition to test the theory, since the eclipse would only be visible in South America and Africa (see [map 2](#) for locations).

The First World War ended just in time, in November 1918, to permit the two expeditions to reach their destinations by May 1919, the month of the eclipse. Eddington led one two-man team to the island of Principe off the west coast of Africa (see [fig. 39](#) for a photo of the eclipse taken in Principe), while Dyson sent two men from his Greenwich Observatory to the city of Sobral in northern Brazil. Difficulties continued during the eclipse, as Eddington encountered clouds that obscured his photographs of the star field around the Sun, and one of the two instruments in Sobral failed to function properly.

After several months of analyzing data in England, Dyson and Eddington concluded that the data agreed with Einstein’s prediction of how much starlight should be deflected from its path by the Sun’s gravity. They presented the results as a test between Einstein’s theory and the classical Newtonian theory of gravity, a test that Einstein’s theory had passed while Newton’s had failed. The news that the most celebrated scientific theory until that time had been overthrown caused a public sensation in many countries. The fact that Einstein, a German, had overthrown the theory of England’s greatest scientist, in a test conducted by Englishmen, seems to have been widely taken as a gesture of scientific truth in favor of postwar reconciliation between nations. No doubt Einstein’s and Eddington’s pacifism and their public opposition to the war played a role in rousing the public as well. Eddington was a Quaker who had risked going to jail by refusing to be conscripted into the British army. Indeed, an anecdote claims that Dyson persuaded the government not to jail him by promising to send him off to Africa to conduct the eclipse observations in lieu of war work. Einstein was widely regarded as the only acceptable German scientist, at a time when German science was broadly and openly boycotted after the war. Indeed, when the Royal Astronomical Society tried to award him its annual gold medal in 1919, the award, as Eddington privately reported to Einstein, was voted down by the full membership, which was unwilling to present the award to a German so soon after the war. No award was made that year, and Einstein finally received the gold medal in 1927 (see [Part I](#), Awards, Honorary Degrees, and Honorary Memberships). Eddington continued to take a great interest in Einstein’s theory in subsequent years and, like Einstein, devoted himself to the task of finding a unified field theory of gravity and electromagnetism that would build on the success of Einstein’s theory.

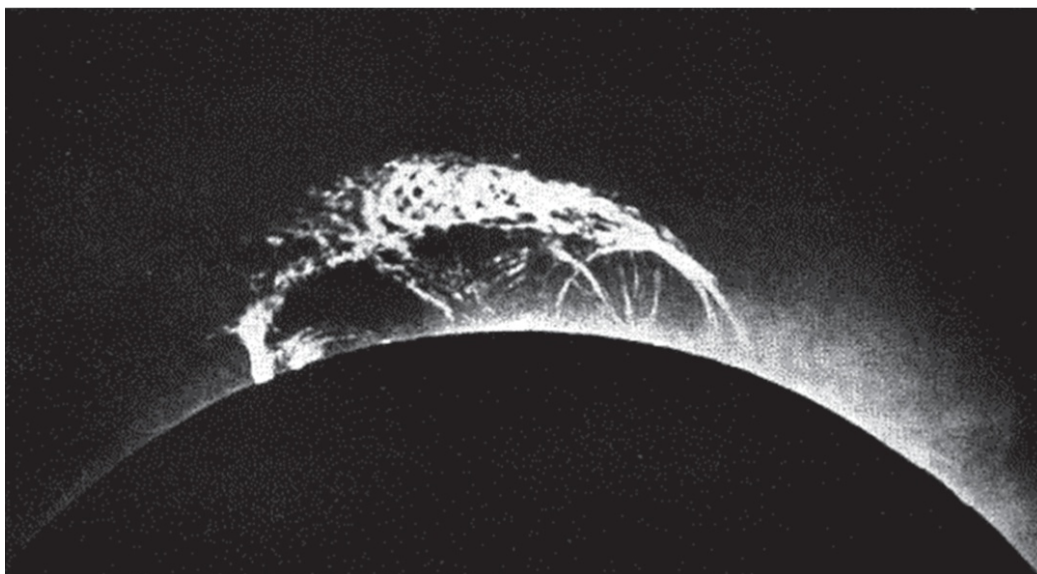


FIGURE 39. The eclipse of 1919. This photo, taken by Arthur Stanley Eddington from the island of Principe, is the best known image from the 1919 eclipse expedition that helped verify Einstein's theory of general relativity. The cloudy conditions on Principe, which hindered Eddington's work, helped capture the remarkable solar prominence that was erupting at the time of the eclipse. (From the collection of the Royal Astronomical Society, London)

Kurt Gödel

Kurt Gödel (1906–1978) was an Austrian mathematician and logician whose works have been widely influential, especially his incompleteness theorem demonstrating that even within an axiomatic mathematical system there may be true statements that cannot be proved from the axioms given. Although his incompleteness theorem grew out of the consideration of number theory, it has been viewed as a profound statement that might apply to many areas of thought. During the Second World War, Gödel and Einstein, both working at the Institute for Advanced Study and both exiles from Nazi-dominated Europe, became close friends, walking home from the Institute together on a regular basis. Einstein accompanied the eccentric Gödel to his interview for American citizenship, fearing that Gödel would say something undiplomatic that might jeopardize his application. Although Einstein apparently discussed his research with Gödel, they never collaborated. However, Gödel did find a metric in general relativity, named after him, which describes a spacetime in which closed, timelike curves are present. Thus, it describes a universe in which time travel is possible.

Fritz Haber

Fritz Haber (1868–1934) was a German chemist whose work had some of the most profound implications for industry and society of any twentieth-century scientist. Using atmospheric nitrogen to produce ammonia (the key ingredient in chemical fertilizers) by supplying hydrogen at high temperatures and pressure, he developed a method of “fixing” nitrogen from the air. This method was turned into an industrial process by Carl Bosch, who founded the IG Farben company. While European countries had been dependent on imports of ammonia-rich fertilizers, the Haber-Bosch process, invented between 1909 and 1913, made it possible for Germany to sustain the homefront during the First World War, in defiance of the British naval blockade that had cut off German access to naturally occurring supplies of nitrate-rich deposits. This development was essential not only to German agriculture but also to the country's war-waging capabilities. Modern high explosives required supplies of nitrogen, resulting in Germany's double dependence on Haber's chemical innovation.

Haber, a Jewish convert to Christianity, was a strong supporter of German and Prussian nationalism. During the war, he was assigned to head the German army's

chemical warfare efforts, which until then had achieved only mixed results. His success in industrializing the production and delivery of chemical weapons made him a hero in Germany and a *bête noire* to scientists (and others) from the Allied countries. Insult was added to injury when he won the Nobel Prize for Chemistry for 1918 (awarded in 1919), at a time when an Allied boycott of German scientists was still in effect. Haber's career was an outstanding example of the successful German state policy of fostering collaboration between academia and industry.

Haber and Einstein had somewhat similar family backgrounds, though Haber, unlike Einstein, was a strong proponent of Jewish assimilation into German society. Strenuously opposed to Einstein's trip to America in 1921, Haber viewed it as consorting with Germany's enemies in the recent war. He thought that participation in an enterprise, directed from World Zionist headquarters in London, gave legitimacy to the argument of some Germans that Jews were disloyal (*see* letter from Haber, March 9, 1921, *CPAE* Vol. 12, Doc. 87; Einstein Archives 12-329). Even so, personal relations between the two men were excellent during Einstein's time in Berlin. They fell equally afoul of the Nazis, thereby vindicating Einstein's opinion that it was folly for Jews to curry favor with German nationalists. Haber resigned from his position as director of the Kaiser Wilhelm Institute for Physical and Electrochemistry in Berlin-Dahlem (Einstein was director of the KWI for Physics) in 1933 rather than dismiss his Jewish staff. He left Germany heartbroken and died the following year in Basel on his way to consider a position in Palestine at a new institute in Rehovot, arranged, ironically, by Zionists. (*See also* Hager, *The Alchemy of Air*.)

David Hilbert

David Hilbert (1862–1943) was a German mathematician who played an influential role in the development of twentieth-century mathematics across a range of topics and fields. After 1912, he became very interested in physics and did much to introduce some mathematical rigor to the subject at a time when physicists were becoming increasingly dependent on some of the sophisticated mathematics introduced in the nineteenth century. He is said to have pronounced that physics was too difficult for physicists. In 1915, he played an important role in the discovery of the theory of general relativity. Einstein had abandoned his effort to find a generally covariant theory of gravity some time before, but was invited by Hilbert to give the prestigious Wolfskehl lectures at the University of Göttingen, where Hilbert was a professor. Einstein's talks aroused great interest there. On the one hand, Hilbert's view that Einstein was on the right track in his geometric approach to physics encouraged the latter to return to his task. At the same time, Einstein's search intensified at the thought of a rival breathing down his neck. (*See also* Rivals.) By November, Einstein had found the final form of his field equations and published the theory as it is known today. The same month, Hilbert submitted a paper that appeared the following March and featured the same field equations. For this reason, some people felt that Hilbert should receive at least partial credit for the discovery, and this circumstance seems to have briefly caused some friction between the two men. However, in recent times, evidence has come to light—in the form of the proofs of Hilbert's paper—which suggests that his original submission may not have contained Einstein's equations (*see* Corry, Renn, and Stachel, "Belated Decision"). This raises the possibility that Hilbert added them to his paper only after he saw Einstein's paper in print.

Paul Langevin

Paul Langevin (1872–1946) was a French physicist with whom Einstein was on very cordial terms. It was Langevin who played host to Einstein during his visit to Paris in 1922, which both men hoped would help heal the rupture between German and French scientists brought on by the First World War. For several years after that conflict, scholars in France excluded their German colleagues from conferences, membership in academies, and access to scientific journals, virtually banishing them from the international "republic of letters." For many but not all French intellectuals, Einstein was exempt from the boycott. A Jew who as a youth had preferred renouncing his German citizenship in favor of taking Swiss citizenship, Einstein was known as a staunch opponent of the war. A visit from such a guest might thus hasten

a scientific rapprochement between the two countries. Interestingly, in spite of his pacifist stance, Langevin himself had assisted the Allied war effort through his work on ultrasonic detection of submarines.

Langevin was closely associated with the Curies, having been a doctoral student of Pierre's and a lover of Marie's after the former's death. He was an outspoken opponent of fascism and lost his academic positions during the Second World War under the Nazi occupation.

An interesting insight into the often central role Einstein's friends—in this case Ehrenfest, Born, and Langevin—played in the history of relativity theory is the following. Paul Ehrenfest introduced the Ehrenfest paradox concerning rigid disks in special relativity, which helped give birth to general relativity; to study this system, one may find it useful to use Langevin observers, who ride upon the disk and whose viewpoint is expressed mathematically in (Max) Born coordinates; this result leads to the definition of Born rigidity in relativity theory.

Max von Laue

Max von Laue (1879–1960) was a German physicist and Nobel laureate who was a close colleague of Einstein's for much of his career. Laue was a very early contributor to relativity theory and one of the first physicists to visit Einstein in Bern to discuss it, in 1906. He received the Nobel Prize with two others for the successful diffraction of X-rays. He and Einstein were colleagues first in Zurich and later in Berlin. Laue was a trustee of Einstein's physics institute of the Kaiser Wilhelm Society since its founding in 1917. Five years later, he was appointed deputy director and took over administrative duties. After Einstein refused to return to Germany in 1933, Laue served as director of the institute throughout the Nazi period (with a four-year hiatus), though he steadfastly opposed the Nazis and their policies. Laue was one of only two members who had the courage to openly support Einstein's decision to withdraw from the Prussian Academy (see [Part I](#), Citizenships and Immigration to the United States). After the Second World War, when Einstein refused to have further contact with most of his former German colleagues, he made an exception for Laue, among a handful of others.

Philipp Lenard

Philipp Lenard (1862–1947), born in Pressburg (today, Bratislava in Slovakia), was an important German experimental physicist who received the Nobel Prize of 1905 for his studies of cathode rays. Among his scientific achievements was the study of the photoelectric effect, in the course of which he clearly demonstrated that the energy of electrons liberated from a metal surface by impinging light was not at all influenced by the intensity of the light. It was the theoretical explanation of this and other features of the effect by Einstein in 1905 that later formed the basis of the latter's Nobel Prize award. In 1907, Lenard received a call to the University of Heidelberg as professor of physics and the directorship of his own institute.

Although Lenard's scientific relationship with Einstein had begun on promising terms, Einstein's later work on relativity theory earned his enmity. A strong German nationalist, Lenard resented Einstein's growing fame and emergence as a spokesman for pacifist and internationalist causes. In 1920, Lenard was linked to a campaign of vilification—which he did not attempt to disavow—to discredit Einstein and the “Jewish physics” of relativity. After taking offense at what he perceived as an attack by Einstein, Lenard confronted him in a debate over relativity at a meeting of the Society of German Natural Scientists and Physicians in Bad Nauheim, accusing him of plagiarism and of devising arguments that ran counter to common sense. Leading figures in German physics, such as Planck and von Laue, defended Einstein against Lenard's charges and tried to smooth the affair over. Lenard was unyielding and became the intellectual father of “German physics” in the Weimar Republic. After the assassination of Walther Rathenau, the German-Jewish foreign minister, in 1922, Lenard refused to fly a commemorative flag over his institute in Heidelberg. He openly embraced the National Socialist movement in 1924 and played a leading role in the governance of German science after the Nazi seizure of power in 1933. His main objective was to uphold the “purity” of German science against foreign, especially British, and Jewish influences.

H.A. Lorentz

Hendrik Antoon Lorentz (1853–1928) was a Dutch physicist who played a central role in the development of the classical theory of electrodynamics. He was, after Einstein, the person most responsible for the emergence of modern relativity theory. His work strongly influenced Einstein, who always admired and even revered Lorentz.

The theory of electromagnetism as derived by James Clerk Maxwell, and further developed by Heinrich Hertz and others, largely ignores the question of the sources of the field and their states of motion. Lorentz was a leading figure in the generation of physicists who came to understand the electromagnetic field as being produced by subatomic charged particles. This microphysical approach generated a revolution in physics, which in the nineteenth century had tended to focus on the bulk properties of matter and energy (the so-called macrophysical approach). Since Lorentz was obliged to deal with the fact that the sources of the field (electrons and other charge particles) were often in motion, he was confronted with questions that naturally led him in the direction of special relativity. He was the first to describe concretely one of the principal results of relativity, the Lorentz contraction, an idea that had previously and tentatively been proposed by the Irish physicist George Francis Fitzgerald. He introduced the notion of different time coordinates for observers in different states of motion and deduced the transformations that preserve the form of the electromagnetic field equations for different inertial observers. These transformations play a fundamental role in special relativity and are named for him (the Lorentz transformations). So important was his role that it was common in the early years of the twentieth century to compare the special relativistic predictions of electrodynamics to those of other theories by describing them as being the predictions of the Einstein-Lorentz theory.

After Einstein became a distinguished figure in the international physics community, he and Lorentz became close colleagues, with Einstein often paying visits to Leyden, where Lorentz remained an external professor at the university. In late 1909, Lorentz yielded his regular appointment at the University of Leyden and became curator of the physics laboratory of Teyler's Foundation in Haarlem. Einstein had great affection for Lorentz, who became like a father figure to him. The most famous disagreement between the two men was that Lorentz was an apostle of the luminiferous ether, the medium of the electromagnetic field, as he saw it, while Einstein made his name as the man who destroyed the ether. Such was Einstein's admiration for Lorentz that in 1920 he gave a talk in Leyden in which he acknowledged that his general theory of relativity had arguably reintroduced the ether to physics in the shape of the spacetime whose changing curvature governed the gravitational field. In 1902, Lorentz became, along with his student Pieter Zeeman, the second recipient of the Nobel Prize in Physics. (See Kox, *Scientific Correspondence of H. A. Lorentz*.)

Walther Nernst

Hermann Walther Nernst (1864–1941) was a German physicist who helped found the modern discipline of physical chemistry. He was one of Einstein's earliest scientific supporters, especially regarding Einstein's work on the new quantum theory and its application to the specific heat of materials. As one of the organizers of the Solvay Conferences, he was instrumental in inviting Einstein to the first meeting of this prestigious group in 1911. Four years later, along with Max Planck, he traveled to Zurich in order to persuade Einstein to accept special membership in the Prussian Academy of Sciences in Berlin, a position for which he also helped to secure funding. Einstein's work on specific heats helped Nernst to formulate the third law of thermodynamics (see Concepts), for which Nernst was awarded the Nobel Prize in Chemistry for 1920.

Nernst and Einstein came from very different backgrounds. Nernst was a Prussian, while Einstein was a Jew from southern Germany, so distrustful of Prussian militarism that he relinquished his German citizenship as a young man. Nevertheless, they had much in common personally. Both had very liberal outlooks and both were practical men, interested in high theory but also fascinated by technology and given to inventing. The latter was a lucrative pastime for Nernst, inventor of the Nernst lamp,

an early and widely used type of electric light bulb.

As a German nationalist, Nernst played an enthusiastic role in the war effort between 1914 and 1918, most infamously as one of the pioneers of gas warfare. Both of his sons perished in the war. His receipt of the Nobel Prize, like Fritz Haber's, was controversial because of his wartime work. Still, he and Einstein remained close colleagues until the seizure of power by the Nazi party forced Einstein into exile and Nernst into retirement. Although Nernst was a Prussian of solidly German descent, he regarded the Nazis' racist ideas as ridiculous (indeed, two of his daughters had married Jews) and refused to participate in their program to "purify" German science and academia. (See Barkan, *Walther Nernst*.)

J. Robert Oppenheimer

Julius Robert Oppenheimer (1904–1967) was an American theoretical physicist who was director of the Los Alamos National Laboratory in New Mexico during the development of the first atomic weapons, a key part of the so-called Manhattan Project. Noted for his mastery of all scientific aspects of the project, he was invaluable for his administrative skill in managing the conflicts between scientists and the military. Oppenheimer was a forerunner in a generation of American physicists who would come to dominate the physics world. In the 1930s he was one of the few American experts on Einstein's theory of general relativity and is remembered for his work on gravitational collapse, which laid the foundation for the theory of black holes that emerged later in the century. After the war and recognition of his role in ushering in the nuclear age, he became the public face of science and a symbol of the burgeoning national security state. He and Einstein became colleagues at Princeton, when he took up the post in 1947 of director of the Institute for Advanced Study, of which Einstein was a member. Accused of membership in the American Communist Party during the McCarthy witch-hunts, Oppenheimer also gained the enmity of Lewis Strauss, a trustee of the Institute, as well as a commissioner and later powerful chairman of the Atomic Energy Commission (AEC). In 1949, Oppenheimer was called to testify before the House Un-American Activities Committee and, five years later, had his security clearance revoked by the Personnel Security Board of the AEC. It was a bitter blow for a former adviser to the National Security Council, who prided himself on his access to the highest levels of power. Einstein had admired Oppenheimer's role in crafting the Acheson-Lilienthal Report advocating the creation of an international Atomic Development Authority and supported him publicly during his ordeal. Privately though, he took Oppenheimer to task for not defying the government and for yielding to requests to testify. Einstein simply "couldn't understand why Oppenheimer had such a thirst for the corridors of power in Washington" (Schweber, *Einstein and Oppenheimer*, p. 271). Oppenheimer died of throat cancer in 1967.

Paul Painlevé

Paul Painlevé (1863–1933) was a distinguished mathematician who was also an important political figure in France. He was an early researcher in general relativity and a co-discoverer of the coordinate system known as Gullstrand-Painlevé coordinates, which are today used to describe the viewpoint of a freely falling observer in the Schwarzschild metric. During Einstein's visit to Paris in 1922, Painlevé pointed out that his coordinate system gave very different predictions for the behavior of the Schwarzschild metric describing the gravitational field of a point mass than did the coordinates used by Schwarzschild himself. He asked if this apparent contradiction did not present difficulties for Einstein's theory, since the same physical field looked radically different if one simply changed coordinates.

Einstein denied that this was a problem for the theory. Neither man seemed to appreciate the true significance of the Painlevé coordinate system: it demonstrated that what was then known as the Schwarzschild singularity (now called the "event horizon") was not a physical singularity, but merely a coordinate singularity. In the Schwarzschild coordinates, a coordinate singularity occurs at the event horizon because an observer far from the black hole (whose point of view this coordinate system represents) will never receive a signal from beyond that point within the lifetime of the universe. A falling observer, however, such as one represented by the

Painlevé coordinates, will eventually receive signals from beyond the event horizon once the observer herself falls through it. The fact that the measurements made by these two observers differ so markedly is simply a consequence of the extreme spacetime curvature passed through by the freely falling observer. Thus, unwittingly, Painlevé had not uncovered a problem with the theory, but rather a clue that could have led to the early discovery of black holes.

Painlevé shared an interest with Einstein not only in relativity theory but also in international politics. Both wished for a more enlightened approach to relations between nations. Painlevé, a man of the left, was twice prime minister of France in the early 1920s. He was part of an administration that ended the occupation of the Ruhr industrial region of Germany that France had undertaken in order to force German payment of reparations under the Versailles Treaty. Painlevé was the principal architect of the Maginot Line, which was constructed to provide a lasting and defensible border between Germany and France.

Painlevé was especially interested in aviation, and, during a later stint as the French Minister for Air, he pursued international agreements to ban bomber aircraft and to establish an international air force that would keep the peace globally. His chief political opponent, the conservative Raymond Poincaré, was a cousin of Henri Poincaré, the famous mathematician and one of the creators of modern relativity theory. Nevertheless, Painlevé's stature in military and aviation matters was such that some of his later ministerial tenure was in governments headed by Poincaré.

Wolfgang Pauli

Wolfgang Pauli (1900–1958) was an Austrian theoretical physicist who was a physicist's physicist during probably the most exciting period in physics history: the rise of quantum mechanics and the rapid development of atomic and nuclear physics in the mid-twentieth century. He was a prodigy who, at age twenty-one, was asked by his adviser, Arnold Sommerfeld, to write a review article on relativity theory for an encyclopedia. The article became a standard reference text for the subject and was admired by Einstein. Even though he was of a younger generation than Einstein, he became and remained throughout his life a trusted colleague of his, eventually becoming one of his collaborators when they worked together in 1943 on a paper on general relativity and unified theory. Unlike Einstein, Pauli was not a theorist who enjoyed occasional experimental work. He promoted himself as the generator of the "Pauli effect," a mysterious field that could cause experiments to break down if he happened to be anywhere in the vicinity. He was sometimes referred to as the "conscience of physics" for his trenchant criticism of the work of other physicists (Paul Ehrenfest addressed him as "the scourge of God" in mocking allusion to Attila the Hun.) His denunciations of some work as "utterly wrong" were not even his highest level of criticism, which he reserved for incoherent arguments that were "not even wrong." His standing in the physics community was second only to Einstein's, causing some to refer to him as "Zweistein." The best known of his many contributions to physics is the Pauli exclusion principle, which states that two particles cannot exist together in the same quantum state. He was awarded the Nobel Prize in 1945.

Max Planck

Max Planck (1858–1947) was a German physicist who played an influential role in Einstein's career as patron and colleague. Planck's great fame rests primarily on his epochal discovery of the quantum in 1900, which inaugurated the great era of twentieth-century physics and for which he was awarded the Nobel Prize in 1918. He showed how the assumption that light confined to a cavity can exist only in little packets of energy called quanta, which are proportional in size to the frequency of the light, made it possible to explain the observed spectrum of blackbody radiation. His insight was unsettling, even to him. It was left to Einstein, beginning with his paper of 1905 on the photoelectric effect, to insist that here was a genuinely revolutionary contribution to physics.

If anything, Planck was an even bigger admirer of Einstein's work on relativity and became one of the earliest physicists to promote his work in this area after 1905. As a longtime permanent secretary of the Prussian Academy of Sciences, his influence

was enormous. He eventually persuaded Einstein to come to Berlin, where the two men were close colleagues for nearly two decades. Although they had quite different political views and social instincts, Einstein greatly respected the older man. Planck was far too obedient to authority, as far as Einstein was concerned, but he sympathized with the constraints within which this leading public spokesperson for science, first in Weimar and then in the Nazi period, had to maneuver. Planck had a tragic personal life, being predeceased by all four of his children. Both daughters died in childbirth (sequentially married to the same husband). One son died during the First World War, while the second was executed by the Nazis for his involvement in the July 20 plot of 1944 to assassinate Hitler. (See also Heilbron, *Dilemmas of an Upright Man*.)

Willem de Sitter

Willem de Sitter (1872–1934) was a Dutch astronomer who played a leading role in the development of modern cosmology in the immediate aftermath of Einstein's discovery of general relativity. One of Einstein's earliest papers after completing the final version of his theory was his famous paper on cosmology that showed how the overall shape of the universe was determined by the mass in it. Einstein's model universe was spherical in shape (or rather hyperspherical, since it was a four-dimensional sphere) and thus closed, or finite in size, even though it had no edge. Einstein had a particular reason for favoring such a universe. He felt that a universe that was infinite in extent but had a finite amount of matter would violate one of the tenets of the theory, something he termed "Mach's principle." Einstein favored a relationalist view of spacetime, based on his reading of Ernst Mach, in which space and time could not exist without matter to measure it by. Thus, unless the supply of mass was infinite, the extent of spacetime could not be infinite, or else spacetime would exist where there was no mass to define it.

De Sitter responded by finding a solution to the theory, now named after him, which described a universe that is infinite in extent but contains no matter. This universe, which is expanding, in contrast to Einstein's model of a static, unchanging universe, is the forerunner of the big bang cosmologies of today. Einstein vigorously debated de Sitter, trying to prove that his cosmology could not be a solution of his theory, but eventually came to accept that general relativity did not incorporate Mach's principle in the way he had thought. De Sitter was one of the earliest adopters of general relativity, and his papers in 1916 served to introduce the theory to the English-speaking world. They also discussed in detail the extent to which the theory made measurable predictions that were distinguishable from those of traditional Newtonian theory.

Arnold Sommerfeld

Arnold Sommerfeld (1868–1951) was a leading German physicist of the early twentieth century. He was an early contributor to the special theory of relativity and, with his theoretical work, played a major role in the development of atomic physics. Although he never won the Nobel Prize himself, several of his doctoral students did, such as Peter Debye, Hans Bethe, Werner Heisenberg, and Wolfgang Pauli. Einstein expressed his admiration for Sommerfeld's abilities as teacher and mentor. Personally teaching an entire generation of German theoretical physicists, Sommerfeld was influential beyond the boundaries of his own institute in Munich, as many of his students, in turn, became prolific mentors to younger physicists. His influence also spread through his publications, which included, apart from his own research papers and his published lectures, the editorship of the physics section of Felix Klein's *Encyclopedia of the Mathematical Sciences*. He also wrote a highly influential textbook on atomic physics that he updated in many editions during the years of major development of modern atomic and quantum theory, from the late 1910s to the early 1930s. Frequent exchanges took place between Sommerfeld's group in Munich and the University of Zurich, where Einstein worked during his early years as a professor. Thus, as young physicists came and went between the two nearby cities, Einstein and Sommerfeld became fairly close colleagues and frequent correspondents. Ultimately, Einstein numbered Sommerfeld among a handful of German physicists who conducted themselves honorably during the Nazi years "within the range of the possible."

Concepts

Action-at-a-Distance—Quantum Teleportation

The key insight that led Einstein to the discovery of special relativity theory was that, in considering the problem of measurement, one is obliged to take account of the time required for information to travel from one place to another. Thus, as explained in the section on special relativity *below*, if one makes measurements at different points in space, and if light is the most rapid method by which one can communicate news of the measurements between the points, it then follows that the speed of light will enter into the equations one uses to describe the different measurements. What if a faster means of communication existed, however? Then the speed of light would play no such role. Consideration of the theory quickly leads to the belief that no speed of communication faster than the speed of light is possible. It is apparently not possible for information to travel faster than this speed in our universe, at least in the classical (as opposed to quantum) theory of relativity.

It was this insight that Einstein used as the basis of his most cogent attack on quantum mechanics in the Einstein-Podolsky-Rosen (EPR) paradox. In modern terms, it poses the question of what happens to purely quantum information when two atoms in an “entangled” state are separated from each other by some distance. Such a state requires that if a measurement is performed on one atom, converting it from a “mixed” state to a “pure” state, the other atom with which it is entangled must then instantly enter the quantum mechanically correct corresponding state. But how can this be if information cannot travel instantaneously across space? This paradox, which Einstein viewed as an argument against the validity of quantum mechanics, has now been accepted as a consequence of the theory that is thus said to have a “spooky” action-at-a-distance aspect to it (ironically, such spookiness is primarily the cause of the widespread and complete acceptance of Einstein’s ideas on relativity).

One of the most talked-about aspects of the development of the EPR ideas is so-called quantum teleportation. Despite its name, quantum teleportation does not involve moving matter around. Instead, quantum information is moved without matter accompanying it. It is worth emphasizing that in spite of the fact that action-at-a-distance plays a key role in this process, one is required to move material objects between the two endpoints of the teleportation and wait for normal light travel times before any “teleportation” takes place. One must entangle two atoms when they are together at one location and then move one of them to the other location by conventional (sublight speed) means. Even then, in order to transport the quantum state from one atom to the other, one must send classical information between the two sites, and this can only proceed at light speed and no faster. Therefore, there is no really practical sense in which one can say that faster-than-light travel is involved in any of the applications of the EPR paradox, including quantum teleportation.

Arrow of Time

Einstein believed that the fundamental laws of physics imposed no directionality on the flow of time. Its laws were completely reversible and made no inherent distinction between past and future. He thought that the fact that time has a direction arises entirely from the existence of very large numbers of particles interacting with one another in the universe. We cannot go backwards in time simply because it is very improbable, not because it is impossible. The past represents a single unique state of such a huge number of particles that the chances of them ever again rearranging themselves into the same pattern are far closer to zero than our minds can comprehend. This view, as applied to thermodynamics (especially with regard to the famous second law), was not unique to Einstein, but he also felt that it applied at least to electromagnetism, among other theories. (*See also* Collaborators, “Walter Ritz.”)

Asymmetric Theory

Einstein's very last research, which occupied the final decade of his life, was based on an asymmetric metric theory. Since a symmetric metric has only ten independent components (the four along the diagonal of the tensor plus the $3 + 2 + 1 = 6$ in the triangle formed on one side of the diagonal), it can account only for the gravitational field, which has ten components in Einstein's theory. An additional six equations are required to define the electromagnetic field, and this is, of course, precisely the number of components found in the triangle on the opposite side of the diagonal. As long as the metric is assumed to be symmetric, as it is in general relativity and throughout the mathematical theory of Riemannian geometry on which it is based, these six components are simply equal to the six on the other side of the diagonal. However, if the metric is asymmetric, then these six components are unconstrained. A difficulty was that the mathematics of such an asymmetric theory was undeveloped, which forced Einstein and his assistants, many of whom were mathematicians rather than physicists, to develop the framework for themselves.

Einstein died while this research program was ongoing. The final report on his efforts was given by his last assistant, Bruria Kaufman, at the conference commemorating the fiftieth anniversary of general relativity that was held shortly after his death in 1955. Ironically, this conference brought together many younger physicists who were eager to explore the possibility of a quantum theory of gravity, an attempt to develop a unified field theory that took an entirely different direction from the one envisaged by Einstein.

Atoms

When Einstein graduated in 1900 from the ETH, the atomic structure of matter was widely accepted in chemistry and physics. There were still prominent skeptics, however, including Ernst Mach and Wilhelm Ostwald, two men whose ideas were familiar to Einstein.

As long as atoms were thought of as impenetrable fundamental particles with no internal structure—the Greek word atom means “cannot be cut”—the division between the macroscopic picture of science (for which the concept of atoms was not required) and the microscopic picture (which depended upon the atomic idea) was not a critical one, though it could be contentious. The statistical approach to physics, which was among the most radical of the microscopic viewpoints, contended that physical phenomena (especially in thermodynamics) could be understood entirely as the consequence of large ensembles of atoms behaving in a statistically predictable manner, with individual atoms obeying Newton's laws of motion. Even proponents of this statistical physics focused their efforts entirely on showing that their calculations agreed with the phenomenologically based results of macroscopic physics. Thus, they adopted a defensive position that insisted it was impossible to disprove the existence of atoms because the atomic picture agreed in every detail with the macroscopic picture. Similarly, it was impossible to prove the existence of atoms, but no one seems to have considered turning the argument around in this way until Einstein began his research career. Einstein expressed surprise, in hindsight, that he was the first to do so.

One major event that had occurred in the years just preceding 1900 was the discovery of the electron, most famously in the work of J. J. Thomson. This finding gave rise to an expectation that the atom really had structure and that electrons came from within the atom. The discovery of fundamental particles such as the electron greatly accelerated the adoption of the atomic hypothesis. Instead of being a useful concept for understanding essentially macroscopic phenomena, atoms became the arena for a whole new branch of microphysics without any macroscopic counterpart.

Even before this new field could mature, however, Einstein had given powerful impetus to the atomic concept by presenting arguments by which statistical fluctuations within macroscopic phenomena could reveal the existence of atoms. Each of these new experiments, as Einstein pointed out, provided new means of measuring Avogadro's number, the most critical quantity in atomic theory, as it represents the number of atoms in a mole of material.

It is worth noting that of Einstein's five papers published in 1905, the two most frequently cited are both concerned with demonstrating the existence of atoms and molecules (the other papers of that year contain the origins of special relativity and the quantum theory of light). *See also* “Brownian Motion” and “Molecular Volume.”

Blackbody (Thermal) Radiation

The study of blackbody, or thermal, radiation played an important role in the development of late nineteenth and early twentieth-century physics. It was a problem in which the two major fields of nineteenth-century physics—thermodynamics and electromagnetism—converged. It was also problematic for the emerging doctrine of microphysics, or atomic physics. Superficially, blackbody radiation was easy to explain by the atomic hypothesis. In this theory, the heat of a body was merely a measure of the kinetic energy of its constituent atoms and molecules. Thus, as a body warmed up, its atoms and molecules would vibrate back and forth more quickly and because atoms are composed of charged particles, this would naturally result in the emission of electromagnetic radiation. The key experimental result was that a body at a given temperature would emit the greatest part of its thermal radiation at a certain frequency. Above and below this frequency, the amount of energy it radiated would fall away. The low-frequency behavior of the spectrum seemed quite comprehensible in the atomic picture, but there was one intractable difficulty with the high-frequency end.

Because a solid body was too complex an entity for the experimental or theoretical study of black bodies, research focused instead on cavities inside metal bodies. The cavity would have a small hole through which radiation could escape, and this radiation would be thermal in nature, its properties determined by the temperature inside the cavity. Conceptually, it was expected that the electromagnetic field inside the cavity would consist of a series of standing waves, bouncing back and forth between the walls of the cavity. Since the energy leaking out through the small hole must consist merely of a sampling of these standing wave frequencies, it was only necessary to calculate which frequencies could produce standing waves in the cavity in order to correctly model the thermal radiation that would be observed. Because only certain wavelengths can fit into the space between the walls of the cavity, it was already expected that a discrete set of frequencies would be allowed in this model, much in the same way that only certain notes can be played on a violin string of a given length.

A key concept invoked during this complex calculation was the equipartition theorem. This theorem insists that if a certain set of frequencies are permitted to exist in the cavity (these are known as the degrees of freedom of the system), then the available energy (determined by the temperature of the cavity) will be equally divided up between these degrees of freedom. Thus, on the low-frequency side of the blackbody spectrum, it was easy to see why there would be a limit on the amount of radiation emitted, because longer frequencies would only barely fit inside the cavity and would therefore have fewer available modes, or degrees of freedom. Since the total energy of the low-frequency part of the spectrum would depend on the number of available modes, it would follow that few modes would mean a relatively low emitted energy at low frequencies. At high frequencies, on the other hand, there seemed no limit to the number of wavelengths that could be squeezed inside the walls of the cavity. As the frequency got higher and higher, the wavelength got smaller and smaller, and it was easy to find any number of modes. If the equipartition theorem really held, the cavity would be compelled to put almost all of its energy into these higher frequencies. In fact, there seemed to be no limit to how many such modes there were. This problem was known as the “ultraviolet catastrophe,” since it seemed to imply that all bodies, no matter how low their temperature, would have to emit most of their radiation in damaging high-frequency form.

This was how things stood in 1900 with the work of two English physicists, Lord Rayleigh and James Jeans. In 1905, the German physicist Max Planck came up with a solution to the ultraviolet catastrophe that seemed strongly counterintuitive but laid the foundations for almost all of twentieth-century physics. Planck proposed that the standing waves inside the cavity were compelled to absorb the available energy in the form of quanta, as he called them: discrete lumps of energy whose size depended on the frequency of the radiation. He invoked what has become known as Planck’s law, to argue that the amount of each quantum of energy E must be given by the frequency of the absorbing radiation f multiplied by a constant h , known as Planck’s constant. Thus $E = hf$ is Planck’s law, which underpins the whole of the quantum theory that would later evolve in the hands of Einstein and others.

Examining Planck's law, we see that it is easy to excite a mode of radiation at low frequencies, because the quantum is very small when f is small. At high frequencies, however, the quantum is much larger, so to excite such a mode even by the smallest amount may be impossible with the energy available. Thus, the equipartition theory is trumped by the quantum law. Though one should share the energy equally between all available modes, there will always be some modes where the allotted portion is insufficient to purchase even one quantum of energy. Those modes will remain unexcited, and it is clear that these will be the highest frequency modes. Calculating with this quantum hypothesis in place, Planck found that he could derive, on the basis of the principles of the statistical atomistic approach to physics, the blackbody spectrum observed by experimentalists.

Nevertheless, the discrete particle-like nature of the quantum was strongly at variance with the spirit of nineteenth-century electromagnetic theory, which insisted that the radiation associated with this field was wavelike and continuous in nature. Planck's innovation seemed partly justified by the discrete behavior already imposed on the radiation in the cavity, so that only certain frequencies could support standing waves. He and others presumed, however, that this would be a situational gambit that could not and should not be repeated when dealing with radiation traveling freely through space.

It was precisely the repetition of Planck's trick that Einstein performed in 1905 in his paper on the photoelectric effect (*see that section below*). Later, he applied the following lesson to a range of unsolved problems in thermodynamics: that the quantum principle modified the equipartition theorem whenever temperatures were low (and thus there was insufficient heat to be divided up evenly) or frequencies were high (and thus even a large amount of heat would be insufficient to be divided up evenly among the high frequencies that would remain unexcited (*see "Specific Heat Capacity," below*)).

Bose-Einstein Condensate

A Bose-Einstein (B-E) condensate is matter in an unusual state in which nearly all of the constituent atoms or particles have the same energy (rather than a random distribution of energies about some mean). The pure B-E condensate, consisting of a gas of weakly interacting atoms at extremely low temperatures, was first produced in the laboratory in 1995. Aspects of the behavior associated with this state of matter are also evident in the concept of superfluidity, in which liquid helium undergoes a phase change at low temperatures where it loses all viscosity, so that the liquid flows perfectly without resisting itself. A current that is set up in a superfluid will continue to circulate almost indefinitely. One reason for the unusual behavior associated with B-E condensates is that all of the atoms are in the same quantum state and behave as a single, coherent entity, without the collisions and dissipation associated with normal matter. B-E condensates represent one of the most intriguing states of matter accessible to physicists. They were first proposed by Einstein in 1925 as a result of his development of the statistical ideas of the Indian physicist Satyendra Nath Bose, and they are one of the key predictions of Bose-Einstein statistics.

Bose-Einstein Statistics

Until the 1920s, the statistical application of Planck's law to kinematic theory was troubling insofar as the logic of the new statistics was not clear. It was understood that quantum statistics made predictions different from classical statistics, and it was clear that many real physical situations involving atoms obeyed these quantum statistics, but the fundamental rules that underpinned those statistics had not been found. Essentially, physicists were still in the business of blindly following Planck's hunch as being the correct distribution of energies in quantum statistics.

In 1924, the Indian physicist Satyendra Nath Bose sent a paper to Einstein that proposed a new way of calculating Planck's distribution function. Bose had been unable to get his paper accepted in any journal and asked for Einstein's help in publishing it. Remarkably, Einstein was able to realize that the paper represented a fundamental breakthrough in the understanding of quantum statistics. According to one version of events, Bose found his statistics after making an error in his efforts to reproduce a statistical calculation for a course he was teaching. The mistake was to

treat atoms or elementary particles as indistinguishable. This was regarded as illegitimate in classical statistics. For instance, if one treats coins as distinguishable, then there are four possible results of flipping two coins, both heads (HH), both tails (TT), heads and tails (HT), or tails and heads (TH). Treating each result as being equally likely, one finds that there is a 25 percent chance of any given result coming up, so that there is a 25 percent chance of two tails and a 50 percent chance of two identical flips. Now suppose, however, that one treats the coins as indistinguishable. Now there are only three identifiable results, HH, TT, and HT. If one treats them all as equally likely, then each has a $33\frac{1}{3}$ percent chance of coming up when the coins are flipped and a $66\frac{2}{3}$ percent chance of two identical flips.

Remarkably, this apparent lapse of logic gives the correct quantum result.

Einstein not only succeeded in getting the paper published, but went on to publish two follow-up papers in which he applied Bose's results to the statistics of light (the photon gas) and to low-temperature gases, and predicted a radical new state of matter, the Bose-Einstein condensate. The statistics he used came to be known as *Bose-Einstein statistics*, and they are understood to govern all quantum particles that have integer spin (non-integer spin particles are governed by Fermi-Dirac statistics, discovered a few years later).

Because of their indistinguishability, Bose-Einstein particles (which include most atoms) can be distinguished from one another only if they have different energies. At low energies, only certain quantum energy states will be available, but this will still be enough to keep the particles distinguishable from one another, and the behavior of the whole ensemble of particles will still be quite classical. However, at extremely low temperatures, all of the particles can fall into the lowest available energy state, the so-called ground state, and become truly indistinguishable. This is called "Bose-Einstein condensation," and such a material will behave in ways that are counterintuitive, becoming a real-life, macroscopic instance of exactly the sort of statistical behavior that seemed so odd and caused Bose's paper to be rejected. In recent years, Bose-Einstein condensates (*see above*) have been produced in the laboratory, vindicating the predictions of Bose and Einstein.

Brownian Motion

Brownian motion is a random motion observed in small particles (for instance, dust) suspended in a fluid. Although the kinetic theory of fluids claims that such particles move in the fluid entirely because of their constant bombardment by the molecules of the fluid, these collisions are so numerous, and so much alike on average, that the motion is remarkably consistent. Thus, the particle may move in a current in the fluid, or may hang motionless in a currentless fluid.

Brownian motion occurs because particles of sufficiently small size may occasionally take part in collisions with the fluid molecules that are particularly violent or lopsided, as the result of random fluctuations in the movements of the molecules. The result is a series of sudden and unexplained, though generally small and short-lived, movements by the particle. These small and random motions were first observed by the Scottish botanist Robert Brown, who gave his name to the phenomenon.

Einstein was able to show that the theory of fluctuations predicts such behavior arising from the kinetic theory of fluids and presented the phenomenon as a test of the physical existence of atoms. Previously, promoters of the atomic picture of physics had often shied away from the notion of a test of whether atoms really existed (*see "Atoms," above*). He presented a precise prediction of the types of motions that should be observed and showed how the details of the motion would relate to the number of atoms present in a given amount of fluid. Thus, he demonstrated a way to measure Avogadro's number, the number of molecules in one mole of a substance. This quantity was not accurately known in 1905 when Einstein published his paper on Brownian motion, and within a few years the French physicist Jean Perrin employed Einstein's calculations to experimentally determine Avogadro's number. For the first time, physicists felt they knew exactly how small atoms really were.

Canal Rays

In the early 1920s Einstein attempted, once and for all, to establish under which circumstances light had the character of a particle and precisely when it behaved like a wave (see “Wave-Particle Duality,” *below*). He devoted himself to designing a series of experiments that, he hoped, would decide definitively between the wave and particle theories of light, as regards the emission of light by matter. It proved very difficult and frustrating to identify an experiment where the theoretical calculations were straightforward enough for the two theories to make testably different predictions without being open to objections on the theoretical side. In some cases, Einstein would find that on closer examination the wave and particle theories did not actually make contrasting predictions. The basic conceptual difference that Einstein aimed to test was whether the emission of light was an extended process, requiring enough time for a whole wavelength to be emitted by the source, or an instantaneous process, requiring only the vanishingly small time required to emit one quantum or particle of light.

By the mid-1920s, Einstein had settled on the notion of using canal rays as the source of light that would be used in the experimental test. Canal rays are ions produced in gas discharge tubes when an electric field is used to accelerate them to high velocities. Einstein therefore required an accomplished experimenter who had worked with the interference properties of the light emitted by canal rays, and Emil Rupp, a young German physicist, was that person.

Einstein proposed an experiment, performed by Rupp, which Einstein initially anticipated would prove that the quantum theory of light was correct and that light was emitted instantaneously. However, during his discussions with Rupp he came to realize that Rupp’s earlier work could only be explained if the classical theory of extended and continuous emission was correct. He accordingly came to expect that Rupp’s new experiments, suggested by Einstein himself, would confirm this result. Einstein and Rupp corresponded intently during these experiments, but Einstein never visited Rupp’s laboratory for fear of angering Rupp’s superior, Philipp Lenard, a bitter antagonist of Einstein’s (see *Colleagues*). In the end, Rupp claimed to have demonstrated the correctness of the classical picture, and he and Einstein published simultaneous papers dealing with the experiment (Rupp’s paper) and its theoretical interpretation (Einstein’s paper).

A decade later, Rupp abruptly fell from grace when it was shown that he had falsified all of his recent results. Although it is impossible to know for sure, the course of his correspondence with Einstein strongly suggests that he also falsified the results of the experiments he performed for Einstein. In this correspondence, as shown by the recent historical work of Jeroen van Dongen, he repeatedly responded to Einstein’s criticism of his results or assertions by claiming to have unconsciously done something Einstein had suggested, or to have suddenly made a breakthrough, alleviating the doubts Einstein had expressed in a letter. It is quite possible that he merely told Einstein what he wanted to hear. The convoluted nature of a fraud interacting with a rigorously honest person like Einstein led to a result proving the opposite of what Einstein had initially expected to find. Because the only way to explain the results Rupp had already claimed to have achieved was to assume the wave theory prediction was true, Einstein naturally switched to this theory at an early stage. Then Rupp merely had to provide evidence in favor of this new expectation, handicapped only by his own inability to properly understand Einstein’s theoretical explication of the experiments.

Cosmological Constant

Einstein's field equations for general relativity initially consisted of only two terms—one describing the mass and other sources of the gravitational field, and one describing the curvature of spacetime produced by those sources. In 1916, in a paper on cosmology, he introduced a third term, which contained the so-called cosmological constant, sometimes also called the *lambda-term* for the Greek letter Einstein used to symbolize the cosmological constant. Einstein introduced this term to solve a problem in his new cosmology. He assumed that the universe is unchanging and eternal, but realized that gravity itself would prevent such a state by causing all matter to fall into itself as a result of its own gravitational attraction.

The lambda-term had an interesting and unusual role in the equations. It opposed the gravitational attraction, having a tendency to repulse matter and increase the spatial separation between objects (we see this effect as operating between galaxies rather than within galaxies and smaller structures).

It is natural to pose the question: Why does the lambda-term have such an antigravity effect when gravity is famously, in all other respects, purely attractive? Einstein soon addressed this topic in another paper, where he pointed out that the cosmological constant serves to introduce a negative pressure that permeates all of space. When we think of antigravity, we naturally think that it must be produced by something that has negative mass, and we know that such a material does not exist (or at least has not yet been found).

In developing his theory, however, Einstein showed that a gravitational effect is not only generated by matter. First, all mass generates gravity, which means all energy generates gravity. Second, he showed that currents of matter produce an extraordinary new kind of gravitational effect that is rather like the magnetic field discovered by Michael Faraday and James Clerk Maxwell. But all of these effects are still produced by mass or energy, which can only be positive. Finally, he showed that stresses and pressures also produce a gravitational attraction. Now, while masses can never be negative, pressures can be. A positive pressure pushes outward, as when a balloon filled with hot air tries to expand. Negative pressures pull inward, as inside a stretched elastic band. The gravitational force associated with a negative pressure, however, is itself negative or repulsive. Thus, if spacetime is permeated by a negative pressure, then the gravitational effect would be to push everything in the universe away from everything else. In recent times, the term *dark energy* has been coined to describe this sort of negative pressure fluid, since it has (positive) energy associated with it. Einstein's cosmological constant is associated with a particular form of dark energy, which can be thought of as vacuum energy, the energy of the fabric of spacetime itself.

In introducing the lambda-term, Einstein apparently failed to notice that the balance between gravitational attraction by all of the normal mass-energy in the universe and gravitational repulsion by the cosmological constant (or dark energy) was fragile and unstable. For a universe of a certain size, a certain value of lambda was required for the balance to exist. If you make the universe slightly smaller, however, the attractive force would be increased (because all of the normal mass-energy would be close together) and it would gradually overwhelm the dark energy, causing the universe to collapse. On the other hand, if you make the universe a little larger, the attractive force would be weakened because the density of normal mass-energy would be decreased. Would not the same be true for the dark energy of the cosmological constant? No, because Einstein's cosmological constant is associated with vacuum energy—the energy of the vacuum—its density never changes as the universe increases in size. Increasing the total volume of spacetime simply creates more vacuum. Thus, as a universe expands, the cosmological constant term (if it exists) gradually comes to dominate its evolution, forcing it to expand at an ever-increasing rate until all galaxies gradually lose touch with one another.

When Einstein came to accept the evidence produced by Edwin Hubble that the universe was expanding, he turned against the lambda-term and decided that it should be dropped from his field equations. A famous story told by George Gamow, one of the founders of the Big Bang theory, claims that Einstein referred to the introduction of the cosmological constant as his “greatest blunder.” Gamow was

known to be something of a joker, and we only have his word that Einstein felt this way, though it is quite likely he voiced such a sentiment. When the other main founder of Big Bang cosmology, Georges Lemaître, proposed to reintroduce the cosmological constant into the field equations (because at the time Lemaître found it necessary to make the universe expand at a slower rate than it appeared to be doing), Einstein warned him that this step was a bad idea. He wrote that he had always had a “bad conscience” about introducing the term in the first place, presumably because it marred the simplicity of the original field equations, and that he thought it should be rejected. Others, such as Arthur Stanley Eddington, did not agree, and ultimately the lambda-term has refused to die, making a huge comeback in recent times with the discovery that the expansion of the universe seems to be accelerating, a result that can most easily be explained by reintroducing the lambda-term.

Cosmology

It is fair to say that Einstein founded the modern field of cosmology. Although interest in cosmological questions can be traced back to ancient times, the subject remained at a relatively unsophisticated level until Einstein inaugurated its modern phase in 1916. The previous half-century had seen a significant development of several important concepts that paved the way for the modern subject of cosmology. The nebular hypothesis—proposing that the solar system evolved from a cloud of gas and dust that collapsed gravitationally upon itself—took shape in the late nineteenth century, although it had already been proposed two hundred years earlier. Another popular topic during this period was the consideration that future evolution of the universe must result in the entropic heat death of the system. Finally, beginning in the mid-nineteenth century with the development of the first really large telescopes, scientists gradually realized that the galaxy was far bigger than the nearby system of visible stars (the rest of our galaxy is obscured, even from most telescopes, by clouds of gas and dust that have not yet formed into stars), and that our galaxy is one of many similar systems of stars. (In Einstein’s time, the word “galaxy” was still used to refer to the Milky Way exclusively. He used the term “island universes” to refer to galaxies other than our own, which were still debatable entities in 1916.)

Nevertheless, the novelty of concepts suggestive of vastness and change is evident in Einstein’s decision to make the first modern model of the universe, one that was finite and static. At this time, astronomy still generated a sense that the universe, as a whole, was essentially unchanging and eternal. While the notion of a spatially infinite universe had been suggested, Einstein was uncomfortable with it for philosophical reasons. His version of Mach’s principle suggested to him that spacetime could not exist as an independent entity. It merely consisted of our interpretation of measurements of distances (spacetime intervals) between events associated with material bodies. Einstein, influenced by the astronomical thinking of his day, thought that we lived in a vast system of stars (the galaxy), beyond which lay essentially nothingness, a void. Since for him spacetime could not exist far from the matter of the galaxy, he reasoned that it followed that our universe must be spatially finite. Yet how could this be without an edge? This dilemma was already known in classical times, and Einstein thought that he had finally found a solution.

The key question Einstein sought to answer with his cosmological model of 1916 was the following: What is the shape of the universe? This question had not yet been advanced at such a sophisticated level of understanding. Everyone, except nineteenth-century mathematicians, had assumed that spacetime was flat in a Euclidean sense. In Einstein’s theory of general relativity (as finalized toward the end of 1915), the geometry, and therefore the curvature of spacetime, was determined by the matter within it. Einstein quickly realized that the overall shape of the universe (in four-dimensional spacetime terms) was determined by the average density of the mass distributed throughout the universe. (Another fundamental assumption Einstein made about his universe, still current today, is that the distribution of matter is homogeneous and isotropic.) With just the right amount (the critical density), the universe, if it had no boundary, would be flat and therefore infinite in extent. Too little, and the universe would have negative curvature and still be infinite. With a greater density than the critical value, however, the universe would have a positive curvature and could be spherical in shape. (Other closed-form shapes, such as a doughnut, are possible but rarely considered.) Strictly speaking, Einstein’s universe is

hyperspherical in shape since we are speaking of a four-dimensional sphere. In this way, the universe would contain a finite volume but still have no boundary.

With his usual insight, Einstein realized that there was a problem with his model. A universe of this sort should collapse on itself due to the gravitational attraction of the mass inside it. In order to fix this problem (because he was sure the universe must be static and eternal), he introduced a new term in his field equations of general relativity: the cosmological constant (*see above*), or lambda-term. This term was helpful in this context because it had a repulsive antigravity effect. It tended to push things apart by increasing the amount of space between them. If its value was carefully chosen, it could just counterbalance the inward pull of gravity. However, Einstein neglected the fact that the balance was fragile and that the slightest push in either direction would cause the universe either to collapse on itself or to expand in all directions without limit.

Almost immediately, objections arose to Einstein's cosmology and a lively debate began, resulting in the birth of our modern Big Bang cosmology. Einstein, inspired by his thinking about Mach's principle, insisted that no spacetime, and therefore no universe, could exist without matter to define it. His own cosmological constant, however, suggested that somehow spacetime had a reality of its own and could grow under its own impetus. Indeed, the Dutch astronomer Willem de Sitter quickly showed how another solution of Einstein's equations could produce a universe with no matter at all that would grow indefinitely.

Later, the Russian physicist Alexander Friedmann pointed out another solution, which is, fundamentally, the one we use in our cosmological models today. Einstein initially tried to show that something was wrong with these solutions, but failed. Then, around 1930, the American astronomer Edwin Hubble showed that nearby galaxies were moving farther away from Earth in a way that was consistent with the expanding universes of de Sitter and Friedmann. Einstein closely examined Hubble's work during his first trip to California in 1931 and concluded that the evidence for an expanding universe was irrefutable. He withdrew his objection to these cosmologies and dropped the strong advocacy of Mach's principle he had upheld until then. He also rejected the cosmological constant since he regarded his motivations in introducing it as being invalid. Ironically, today the cosmological constant plays a major role in cosmology, after the discovery that not only is the universe expanding, but its expansion is accelerating, a result that can be very neatly explained by the cosmological constant.

Today we have reversed our position on Einstein's cosmology. We no longer believe the universe is finite but eternal, instead believing it is infinite in spatial terms but not infinitely old. We now have evidence that the universe is either perfectly flat or very close to it, and Einstein's theory insists that such a universe must be infinite—unless it has a boundary or is very slightly non-flat and thus technically finite but far vaster than it is possible for us to see. In addition, we now have strong evidence that the universe is expanding and—barring certain possibilities now thought to be unlikely—this implies that in the distant past it was vanishingly small. Thus, the universe began in what has been called a Big Bang, because putting all the energy in the universe into such a small volume must be associated with an incredibly hot and violent initial expansion.

Determinism

This concept is often said to be the issue over which Einstein broke with the quantum theory when it evolved into quantum mechanics. Determinism is the notion that, given perfect knowledge of the initial conditions of a system (where every particle is and what it is doing), we ought to be able to use the equations of physics to predict exactly all future events in the system. Strictly speaking, however, the issue that drove Einstein to reject quantum mechanics was the question of separability. It was always rather a dubious proposition that the future history of an entire system could be plotted in advance. But Einstein seems to have held firm in the hope that the future course of an individual particle should be deducible from its current state, independent of what might happen to other particles, unless it interacted with them in the future. But quantum mechanics allowed for entangled states in which two or more particles shared a wave function and were thus bound together in terms of future measurements of their properties, even if they did not interact again. It was

this feature of quantum mechanics that he and his collaborators chose to highlight in the Einstein-Podolsky-Rosen paper (see “Action-at-a-Distance,” *above*). Ironically, some physicists now propose that the best way to produce entangled states for many atoms at once is to use Bose-Einstein condensates (see *above*), whose existence Einstein first predicted.

Distant Parallelism

One of the difficulties introduced into physics by general relativity is the problem of how vectors move from one location to another in a curved space. In flat space, the vector must always remain parallel to itself as it moves, and we can claim to be using directions defined by the flat space itself as a guide in that process. In curved space, however, the vectors associated with the dimensions of spacetime themselves change direction as one moves from one place to another. This implies that “parallel transport” of a vector depends on the structure of spacetime itself, something that mathematicians had already carefully studied before Einstein came along. In general relativity, the details of the metric (which describes how to measure distances in curved spacetime) are used to determine the “connection” that describes how vectors are parallel transported. An alternative approach, adopted by Einstein in his distant parallelism theory, is to let spacetime be flat (thus the metric tells us nothing of interest), but to allow the affine connection that defines parallel transport of vectors to contain the fundamental variables of the theory. By allowing the affine connection to be asymmetric, Einstein introduced a torsion, as it is now known, into the theory. This torsion can be associated with the notion of the spin of elementary particles, such as the electron and proton.

This theory of Einstein’s had been previously developed by the French mathematician Elie Cartan. Cartan had even tried to explain the theory to Einstein during the latter’s trip to Paris in 1922. It seems that Einstein really had not understood Cartan’s work at that time, and he did not associate Cartan with the theory he worked out later in the decade. The theory is known as the Einstein-Cartan theory. Einstein generally preferred to work things out for himself rather than to read the mathematical literature, which helps explain his failure to acknowledge Cartan.

In Einstein’s version of the theory, he introduced a tetrad, a four-dimensional, vectorlike entity, to describe how vectors were transported through spacetime. The tetrad field had sixteen degrees of freedom associated with it, which Einstein thought would be the perfect number to encompass the ten degrees of freedom of the gravitational field and the six of the electromagnetic field. However, it was very difficult to produce actual field equations for the tetrad components, and those that Einstein found did not seem to reduce to the correct physics. He nevertheless persisted, working with a mathematician, his assistant Walther Mayer, by taking a page from Theodor Kaluza’s book. He added a fifth dimension to his distant-parallelism scheme, which allowed him to introduce an extra vector with his tetrad. With this new scheme, Einstein and Mayer had more luck deriving the correct field equations of gravitation and electromagnetism, but no success in finding solutions corresponding to known particles, or in gaining some insight into the quantum problem.

$$E = mc^2$$

Without a doubt, the most famous equation in science is Einstein’s formula for mass-energy equivalence, commonly written as $E = mc^2$. Einstein first realized that such an equation was implied by his new theory of relativity almost immediately after he had published his 1905 paper that established the theory. He then wrote a new paper, another of the remarkable papers of his miraculous year, arguing that the kinetic energy of a body contributes to the mass or inertia of that body. He showed that the equations of relativity worked out in his previous paper implied that if a particle emitted light beams, an observer in motion with respect to that body would naturally observe a loss of energy by the body (equal to E), but would also observe a change in its mass, according to the relation $E = mc^2$.

One way to think about Einstein’s result is in the following terms. Consideration of time dilation and length contraction as shown in Einstein’s first paper on special relativity suggests that bodies cannot reach the speed of light relative to other

observers because those observers would see the body shrunk to zero length, with clocks that had stopped running, so that they were frozen in time. Why then is it not possible to simply accelerate a body to light speed in the usual way? It turns out that as a body gains kinetic energy from its motion, it also increases in mass (as measured by these other observers), making further acceleration more difficult. As a body approaches the speed of light, its mass increases without limit, making further acceleration (relative to those other observers) impossible, no matter how much energy is expended.

Einstein subsequently worked out a thought experiment that cleverly demonstrated, in a conceptually very clear way, why light must have mass. It had been known since Maxwell that light carried momentum and could apply a pressure, known as radiation pressure, on objects that absorbed it (and a corresponding recoil from emitters). Einstein observed that if light did not have mass, it ought to be possible to power a spaceship from the inside using the same light energy over and over again—simply by transmitting it from one end of the ship to the other and then sending the energy back to the front of the ship by electrical circuitry. The light, emitted from the front of the ship, would set the ship in motion by its recoil. This motion would be arrested when the light was absorbed at the back of the ship, but not before the ship had moved a short distance. If the energy could then be routed back to the light source at the front of the ship, one could simply repeat the same action indefinitely unless the center of mass of the spaceship had not actually been moved (which is our usual experience, that one cannot move without pushing off something external to the ship). But since only the light beam has changed position, if we assume the ship's center of mass moved, it can only be because the light beam has mass. A simple calculation demonstrating how much mass is required yields the famous formula.

Given the familiar form by which the equation has become so widely known, it is interesting to note that Einstein did not write it in this way in any of his early papers. Instead of using E for energy, he wrote L because his early arguments involved the mass of light energy (or K where he discussed kinetic energy), which is usually written with that letter (related to the word “luminosity”). Instead of writing the conversion factor of c^2 on the side with the mass, he wrote $m = L/c^2$ since the thrust of his arguments was that if one knew the energy of a beam of light, one could work out its mass using this equation. (See also no. 181 in [appendix C](#).)

Ehrenfest's Paradox

In 1909, Paul Ehrenfest (see [Part I](#), Friends) drew attention to a difficult puzzle posed by the phenomenon of length contraction in special relativity. Suppose one constructed a disk out of metal or some other rigid material and then set this disk into motion. An observer not rotating with the disk could try to measure its diameter and circumference by placing meter disks on the disk so that the meter sticks rotate with the disk; then the observer would count how many of the disks were needed to cover the distances involved. Because the meter sticks placed along a diameter would be moving perpendicular to their length, they would undergo no contraction. The meter sticks placed on the circumference, however, would experience a contraction. Since all these meter sticks would be shortened, it would take more of them to span the complete circuit of the disk. The nonrotating observer would thus insist that the circumference of the disk, when rotating, was greater than it was when at rest. The diameter being unchanged, the ratio between these two quantities, usually known as π , would actually be different for the rotating disk and the nonrotating disk. If the disk were truly rigid, it would burst when set into motion. Most of those who responded to Ehrenfest's idea focused on the implication for the concept of rigidity.

Ultimately, it was concluded that perfectly rigid bodies could not exist in special relativity because their rigidity would require that their internal speed of sound be greater than the speed of light. Einstein, on the other hand, focused on the interesting fact that the geometry of the rotating disk was different. He concluded that the different geometry was caused by the acceleration associated with rotational motion. His idea of the equivalence principle suggested that if acceleration could generate a change in geometry (which amounts to a curvature of space and time), then so could a gravitational field. It seems to have been this analysis of the rotating disk that first convinced Einstein that a relativistic theory of gravity must be a theory based on the

concept of a curved or non-Euclidean spacetime geometry that is altered by the presence of massive objects.

Einstein-Podolsky-Rosen (EPR) Paradox

In 1936, Einstein, together with two young physicists working at the Institute for Advanced Study in Princeton (Einstein himself had taken up his position there three years earlier), developed a thought experiment that addressed one of Einstein's core objections to quantum mechanics. The thought experiment was highly influential, inspiring work in two different areas of physics.

The first was a search for so-called hidden variables theories, with the hope that they would explain quantum behavior by demonstrating that some information stored in quantum particles was hidden from us and that fuller knowledge would restore an essentially classical picture of how they interacted. This line of work, though it aligned more closely with Einstein's views, ultimately proved less fertile than the quantum-mechanical concept of entanglement that the paper introduced, which asserts that quantum particles can enter states in which the laws of measurement tie their physical properties together, even if they are no longer physically close to one another. The concept lies behind a great deal of activity in modern physics, including the subject of quantum computing. The paper, written purely as a thought experiment in typical Einsteinian fashion, has also in recent times formed the basis for several famous real experiments which demonstrated that if quantum mechanics were really true, the paradoxical effects predicted by Einstein and his collaborators do in fact occur in nature.

The EPR paradox, as it is known, depends on the Heisenberg uncertainty principle, which states that certain pairs of measurable quantities are tied together by the rules of quantum mechanics. Thus, if two particles interact, for instance by colliding off each other, we can expect their energies to be linked by the conservation laws of physics. If the two particles now move off without our first measuring these momenta, however, we would have very uncertain knowledge of what these momenta are.

According to the Copenhagen interpretation of quantum mechanics, promulgated by Niels Bohr and famously opposed by Einstein, only by measurement can we break down the wave function of the particles and find out what their momenta actually are. Now suppose that, after the particles are separated by some distance, we locate one particle and measure its energy. In doing so, the conservation laws now tell us the energy of the other particle, even though we never measured it. We have somehow instantaneously broken down its wave function at a distance.

Should this instantaneous effect count as sending a signal to the other particle, a signal that violates the rules of Einstein's theory of relativity that no signal can travel faster than the speed of light? Einstein argued that if the doctrine of local realism was to be maintained, the result must be that quantum mechanics is an incomplete theory. This argument was later interpreted as a claim that a more complete theory exists which contains certain hidden variables determining the details of the whole interaction between the particles in a way that is hidden from us at present.

Later, Yakir Aharonov and David Bohm modified this thought experiment so that the spins of the two particles were the entangled quantities. Bell's theorem states clearly that if it is possible to perform the thought experiment in real life, then it does constitute a violation of nonlocality in physics (or even a violation of realism, appropriately defined). Several experiments have since been performed, and all show that the results are in agreement with the predictions of quantum-mechanical entanglement.

Einstein, Podolsky, and Rosen were arguably advancing a *reductio ad absurdum* argument to show that QM could not be true because it led to impossible predictions. This then is one of the interesting cases in the history of science where such an argument has subsequently revealed precisely what occurs in nature; another one concerns the discovery of the wave nature of light and of what is called the "Poisson spot."

Einstein-Rosen Bridge

The Einstein-Rosen bridge is a spacetime structure that was proposed by Einstein and his assistant Nathan Rosen in a 1936 paper. Today it is more commonly referred to as a *wormhole*. In their paper, Einstein and Rosen were seeking a useful model for subatomic particles that avoided the use of so-called singularities in the gravitational field. They realized that if the universe was thought of as consisting of two separate sheets of spacetime, then the particles could be modeled as small tubes or tunnels (or a bridge, as they called it) between the two sheets. Electric field lines that entered the bridge would emerge on the other sheet. Thus, observers from one sheet would see field lines disappearing into or emerging from the location of the bridge, which is what we see when we observe the electric field of a proton or electron. Einstein's motivation was to see if a model such as this would provide a way in which his theory of general relativity could explain the quantum behavior of fundamental particles without the need for quantum mechanics, which troubled him. The bridge model was never accepted as a possible model of subatomic particles but has remained popular because its existence would conceivably raise the prospect of providing a shortcut (a form of faster-than-light travel) to distant parts of the universe. Even more alluringly, studies since the 1980s have suggested that wormholes, if they existed, might make it possible to construct "closed timelike curves," or time machines.

Equipartition Theorem

Einstein's use and mastery of the equipartition theorem was one of the signature characteristics of his early work in physics, in particular in his elucidation of the nature and applicability of the concept of the quantum. The equipartition theorem states that when a system consisting of very many particles reaches equilibrium, the available energy will be distributed equally among all of the possible degrees of freedom, or varieties of motion in the system. This means, of course, that all groups of molecules will have, on average, the same energy as the others. It also means that the different directions of motion that the molecules will have will also get equal amounts of energy. Thus, the molecules will not prefer to go up rather than sideways. If they can rotate, they will also rotate with the same energy with which they move in any given direction.

It was the failure of calculations based on the equipartition theorem to correctly derive the curve for blackbody radiation that led Max Planck to introduce the quantum hypothesis. He did this because, in this particular situation, there were so many high-energy states that it seemed as if almost all the energy in a black body should end up in the high-energy, high-frequency states. Since each state receives the same amount of energy as any other, it follows that if a particular regime, such as high frequency states in this case, has a much greater density of states, those regimes should have most of the energy. Thus, it appeared as if most bodies, even cool ones, should glow in the ultraviolet, in defiance of all experience that only very hot bodies do.

Einstein's solution was to observe that Planck's quantum implied that there was an important exception to the theorem. If one could only have energy in packets (or quanta) and the minimum number of packets was one, it followed that when energy was relatively scarce, it might be impossible to afford even one quantum of a relatively high-frequency—and thus, by the Planck law, high-energy—state. In the blackbody case, therefore, the nearly infinite number of high-energy states would all have exactly zero actual energy, since the only alternative to having one quantum of energy is to have zero. In the case of specific heat capacities, Einstein showed how, as the temperature dropped, and thus less overall energy was available, more and more energy states would become unaffordable, since even one quantum of energy would be more than the average energy available. The result was the prediction that became known as the third law of thermodynamics—that as the temperature went toward absolute zero, all materials would lose the capacity to retain heat, because their specific heat capacities would become zero.

Fluctuations, Theory of

Another signature characteristic of Einstein's early work in physics was his mastery of statistical physics and his pioneering examination of the physical effects of statistical

fluctuations. The nineteenth century had seen the development of the kinetic theory of matter, based upon the microphysical picture of reality, which claimed that matter consisted of elementary particles (atoms and molecules) that individually obeyed the Newtonian laws of mechanics but collectively could only be understood in terms of their statistical behavior.

The two most famous names associated with this nineteenth-century development were James Clerk Maxwell and Ludwig Boltzmann. The statistical physics they produced provided a thorough understanding of how most of thermodynamics, one of the key macroscopic theories of physics (that is to say, theories concerned with the behavior of matter in bulk), could be understood as the average behavior of large ensembles of atoms (as given by Avogadro's number). Thus, by 1900, the statistical approach to physics had concentrated on showing that there was no way to prove that atoms did not exist, because the predictions of atomic theories of microphysics were indistinguishable, in the mean, from the predictions of macroscopic theories and experiments.

Einstein turned the subject on its head by setting out to prove the existence of atoms. He asked himself in what way the statistical theory could predict effects that would be different from what one would expect of matter that was continuous and not composed of atoms. He did this by developing the theory of fluctuations, which analyzes the apparently random departures from the average that are the result of the motions of atoms and molecules that are out of the ordinary. In 1905, he showed how the phenomenon of Brownian motion (*see above*), about which he knew little, could be understood in terms of these fluctuations.

Beginning in 1905, Einstein transformed the microscopic understanding of physics in an even more revolutionary way. He took up Planck's concept of the quantum, an indivisible packet of energy, and proposed that light was actually composed of such quanta. This ultimately gave birth not only to the concept of the photon but also to a realization that the physical laws governing the motions of the elementary particles such as atoms (and the constituent particles of atoms) were not actually Newton's laws at all, but a different set of quantum laws. The struggle to develop the laws of quantum mechanics was difficult and protracted essentially because it placed physicists in the position of describing the behavior of particles too small to be seen, which obeyed laws that could only be discovered by observations of those very particles. The ironic result was that the new laws of quantum mechanics, as they emerged in the 1920s and '30s, demonstrated that the statistical approach to physics, of which Einstein had been one of the great masters, had to be applied not only to ensembles of particles but even to individual particles. Einstein was unable to accept this viewpoint, to the surprise of many of his younger admirers.

Ghost Field

It is difficult to reconstruct Einstein's ideas on the ghost field (*Gespensterfeld*), as he never wrote on this topic. Everything that is known about it comes from others commenting on his idea (primarily H. A. Lorentz; *see* Colleagues). There is evidence that Einstein's ghost field played an important role both anticipating and inspiring the early interpretation of quantum mechanics, known as wave mechanics, in which each particle has a wave associated with it, which is interpreted as the probability function of the particle. In other words, there is a quantum particle whose precise whereabouts are unknown, but which is more likely to be in certain places where the amplitude of the wave associated with the particle is particularly great. This wave was the ghost field.

Gravitational Waves

The concept of gravitational radiation was inspired largely by the development of special relativity. A number of important researchers in this area, including Henri Poincaré and Max Abraham, had referred to these waves and debated the possibility of their existence before Einstein ever discussed them in public. When he did so in 1916, however, it was to present the first concrete mathematical description of them, within the framework of his then new theory of general relativity. That first paper was marred by errors that were corrected in a second paper published in 1918, in which Einstein presented the theory and the equations that continue to underlie the

study of gravitational waves today.

Einstein returned to the topic in the mid-1930s in collaboration with his assistant, Nathan Rosen. Because Einstein's previous papers had dealt with only an approximation of these equations (the linearized approximation), they hoped to improve upon the earlier work by finding an exact solution to Einstein's equations representing these waves. Together the two physicists submitted to the *Physical Review* an article titled "Do Gravitational Waves Exist?," proposing that the answer was no and presenting a proof of it. The journal returned the paper to Einstein together with a critical ten-page referee's report. Irrked, Einstein withdrew the paper in an angry letter to the journal's editor and resubmitted it to another journal. Before it could appear, he was obliged to completely revise it, reversing its conclusions. A colleague at Princeton, Howard Percy Robertson, had convinced him that he had actually stumbled upon a valid, exact solution for gravitational waves without realizing it. Robertson had become friendly with Einstein's new assistant, Rosen's successor Leopold Infeld, which seems to have given him occasion to point out the flaw in Einstein's argument.

Ironically, we now know from the records of the *Physical Review* that Robertson had been the referee who had earlier pointed out the problems with the paper, but whom Einstein had ignored. Besides altering the paper with Rosen, Einstein's change of heart also prompted him to abandon a manuscript in progress that explored further consequences of the unexpected result of his work with Rosen. Nevertheless, in the version of the paper that eventually appeared in print, Einstein still devoted some space to the question of whether binary star systems, the likeliest practical source of gravitational radiation, would actually emit waves. He also offered reasons why that might not necessarily be the case.

Following Einstein's death, the topic of gravitational waves became the source of some controversy. Einstein's two former assistants, Rosen and Infeld, championed the view that gravitational waves could not be emitted by binary stars and therefore would likely never play a role in real-world physics. Gradually, further theoretical work undermined this position, though as late as the mid-1970s Rosen finally wrote an article with the title "Does Gravitational Radiation Exist?"

Also in the mid-1970s, however, came the discovery by Russell Hulse and Joseph Taylor of Princeton University of the first binary pulsar system, an unusually close and rapidly orbiting binary star system consisting of ultracompact pulsars, or neutron stars. By 1979, Taylor and Hulse showed that this system was decaying in its orbit at a rate in good agreement—later upgraded to excellent agreement—with Einstein's prediction in his 1918 paper using the famous quadrupole formula. This was the first experimental evidence that gravitational waves do in fact exist. Hulse and Taylor were jointly awarded the Nobel Prize in Physics in 1993 for the discovery of a new kind of pulsar that opened up further possibilities to study gravitation.

Efforts to detect gravitational waves began around 1960, pioneered by Joe Weber. This effort also became mired in controversy during the 1970s when Weber's claims to have detected gravitational waves with his instruments were contested and rebutted by other experimenters. Efforts to detect gravitational waves arriving on Earth continue with large-scale projects such as those at the Laser Interferometer Gravitational-Wave Observatories (LIGO) at Caltech, MIT, and in Washington State and Louisiana in the United States (the detectors were originally designed and developed by teams at Caltech and MIT), and the Virgo interferometric antenna for gravitational wave detection at the European Gravitational Observatory (EGO) near Pisa in Italy. (See also Kennefick, *Traveling at the Speed of Thought*.)

Gravito-Magnetism

Einstein's theory of general relativity did not simply replace Newtonian gravity with a new version that was compatible with Einstein's relativity theory. It was a radically new theory. Remarkably, it happened to make predictions for all of the traditional tests of gravity experiments that are very close to those of Newtonian gravity. It also proposed a whole new range of gravitational effects in no way envisaged by Newton's theory. This was because Einstein's theory, as a field theory, also had many similarities to Maxwell's theory of electromagnetism. Maxwell's theory, of course, predicted electric fields that behaved much like traditional Newtonian gravity. Einstein's general relativity also proposed that moving masses, just like moving

charges in Maxwell's theory, would produce effects much like Maxwell's magnetic forces. These effects are usually referred to as gravito-magnetism. They remain of extraordinary interest, partly because of their novelty compared to traditional Newtonian tests of gravity, and partly because of the great difficulty of observing them or reproducing them in the laboratory. To date, the effects of gravito-magnetism lie at the margins of detectability, which is why Einstein's ability to predict them so accurately is all the more remarkable.

The best-known experimental prediction of gravito-magnetism is the Lense-Thirring effect, or frame-dragging, which is a precession induced in other bodies by a rotating gravitating mass. A star, planet, or black hole that spins does not merely attract other bodies by its gravitational attraction but also drags along their inertial frames, causing them to undergo a form of precession. One can think of this dragging of inertial frames as a rotating body dragging spacetime itself around in its vicinity. While the effect is thought to be very dramatic in the vicinity of black holes that rotate rapidly, it is very hard to detect in the solar system. Tests such as the NASA Gravity Probe-B mission have found evidence that the effect is real and about the size predicted by Einstein's theory, but at a relatively low level of accuracy. Some other solar system tests also provide some evidence that the effect is real.

Another gravito-magnetic phenomenon is gravitational radiation, also a notoriously hard-to-detect effect of the theory (see "Gravitational Waves," *above*).

Hole Argument

During the later stages of his search for the correct form of the field equations of general relativity, Einstein began to fear that it was impossible to find a generally covariant system of equations.

When he published the *Entwurf* (outline) form of his theory (in collaboration with Marcel Grossmann; see [Part I](#), Friends) in 1913, he renounced this goal (general covariance) of an invariant tensorial set of equations which would have the same form for all observers. To explain this failure in his original program, he advanced the hole argument, which pointed out that generally covariant equations would permit a situation in which the same system of matter (let us say, the Sun and the planets of the solar system) could predict different fields as far as the spaces (or holes) between the planets were concerned. Different observers would be entitled to say they saw a different mathematical form for the gravitational field within these holes. Thus, a generally covariant theory would not predict a unique solution for a system like the solar system. When, in late 1915, Einstein succeeded in finding a generally covariant tensorial form of his theory, he realized that the hole argument was flawed. The merely mathematical description of the gravitational field was not observable. Once two different observers tried to actually calculate the trajectories of particles moving through the holes (each doing so within their own coordinate system), they would discover that they agreed about the actual trajectories.

Einstein was thus perhaps the first to realize the importance of gauge invariance in modern field theories. The field itself is not an observable one and retains a degree of flexibility expressed in the choice of coordinate system or "gauge." The predictions of the motions of physical particles are still invariant in spite of this gauge freedom.

Length Contraction

Relativistic length contraction, also known as Lorentz-Fitzgerald contraction, is one of the key experimental predictions of special relativity. It proposes that objects in motion, with respect to the person measuring them, undergo a contraction, or shortening, in their length (compared to their length when at rest with respect to the same observer) by an amount that depends on the square of the ratio of the object's velocity to the velocity of light in empty space. It had been proposed before 1905, most importantly in the work of the Dutch physicist H. A. Lorentz.

Earlier physicists, such as Lorentz, proposed length contraction as a dynamical effect to be understood as a result of a force produced on moving bodies by the electromagnetic field. Einstein's theory radically reinterpreted it as a purely kinematical effect that was merely the result of our attempt to use light as a medium by which to make measurements of the length of a moving body. For Einstein, length contraction was a direct consequence of the relativity of simultaneity and of his

realization that measurements of length are actually measurements of a spacetime interval between two events (as opposed to a purely spatial distance between two places). The events are the measurement of the current positions of the two ends of the object whose length is measured.

If one is at rest with respect to the object being measured, then it is trivial to measure the two ends at the same time. In this case, the time elapsed between taking the measurements is zero and therefore the spacetime distance (or interval) between the two events is simply the proper length of the object, to use relativistic terminology. If the object is in motion, however, then if one tries to receive information about the measurement of one end from a position at the other end, the fastest way to receive the information is by sending a light beam. In the time it takes the light beam to arrive, however, the position of the other end will have changed because of the motion of the object. Thus, time and space are intermixed in the measurement of the length of a moving object. Einstein's insight was that it was the spacetime interval between the two events that was an invariant quantity, where an invariant quantity is one whose measurement both moving and non-moving observers would agree on. The purely spatial length was not, and simple geometrical arguments could be used to derive the Lorentz contraction from this insight.

A key difference between Einstein and Lorentz was that for Lorentz the moving body was really contracted. For Einstein, two people in inertial motion with respect to each other would each insist the other was contracted, because the contraction was merely the result of the measurement they were making, not an actual physical shortening of the objects involved. The concept of length contraction as envisaged in Einstein's theory also focused on the question whether it was really physical to speak of perfectly rigid objects, as physicists had been wont to do (*see "Ehrenfest's Paradox," above*).

Metric

The metric of spacetime is a mathematical way of describing how to turn coordinate measurements into actual distances (or intervals) in spacetime and thus also a way of describing the geometry of spacetime in terms of those measurements. We can think of the metric as a generalization of Pythagoras's theorem. If we wish to measure the distance between two cities on a conventional (Mercator projection) map, we can use the lines of latitude and longitude on the map as a guide and measure how far east one is from the other, and then how far north. The square of the actual direct or straight-line distance between them will be equal to the square of the eastward distance plus the square of the northward distance.

We are not obliged to use just this one type of (Cartesian) coordinate distance, however. If the map is printed with polar coordinates, then we can measure the radial distance between the cities (how much farther one is from the pole than the other) and the angular distance between them (the angle between the lines drawn from each to the pole). A somewhat different, but fundamentally similar, formula then permits us to obtain the square of the physical distance between them. The metric is a shorthand way of describing the difference between the two ways of writing Pythagoras's theorem (that is, in Cartesian and in polar coordinates).

If, instead of a map, we had a globe depicting the position of the two cities, we could still have a coordinate system of lines of latitude and longitude imposed on the globe. However, any formula that showed how to turn measurements of the coordinate distances between the cities into the actual distance between them would have to take account of the fact that the geometry was no longer that of a flat page but of the curved surface of a sphere. Once again, however, the metric could provide a shorthand way of remembering the correct formula.

The metric was introduced into relativity theory by Hermann Minkowski, who observed that Einstein's special theory of relativity was much like the first case discussed above—of the flat map described in different coordinate systems. Different inertial observers in motion without acceleration with respect to each other would encounter the same "flat" geometry of spacetime (now called Minkowski spacetime) but would measure distances and times in it with different coordinate axes, depending on their relative speeds. Just as a map maker using the pole star to find north and another using a magnetic compass will disagree somewhat about the direction of their north axis (since the magnetic pole of the Earth does not coincide

with the north pole of the Earth's axis of rotation), so two inertial observers in motion with respect to each other do not agree on the direction in which their axis of time points in Minkowski space. Nevertheless, although their coordinates are different, they experience the same metric, and the mathematical language of the metric permits them to reconcile the measurements made with their different coordinate systems. They can transform their relative measurements of time and space into invariant spacetime intervals upon which they both agree. Likewise, the two map makers mentioned above, who disagree on measurements of how far north one city is from the other, will agree on the actual distance between the cities as long as both make reliable measurements of both north and east distances (recall that the actual directions of north and east are not the same for them) and combine them correctly.

Initially, Einstein was unenthusiastic about Minkowski's reformulation of his ideas on special relativity. However, he quickly came to realize the power of this approach when he tackled the problem of a general theory of relativity. Whereas the special theory dealt only with unaccelerated inertial observers, the general theory was intended to provide a way in which noninertial observers (those in a state of accelerated motion) and observers in a gravitational field (who by Einstein's understanding of the equivalence principle counted as noninertial observers) could reconcile their measurements of space and time. Einstein realized that this case is like that of the person who uses a globe to measure the distances between the two cities. For noninertial observers, spacetime is no longer the flat spacetime of Minkowski; it is curved. One still has a fundamental ability to impose different coordinate systems upon it, but now different observers may actually disagree about measurements of space and time because their local geometry is actually different from each other.

For instance, an observer on the surface of a massive planet is in a (slightly) curved spacetime, whereas one in empty space is experiencing flat spacetime. Once again, the metric provides the language in which they may reconcile these differences in measurement. Fortunately for Einstein, nineteenth-century mathematicians had formulated the mathematical language for doing so (in particular Riemannian geometry and tensor calculus), and he was able to find a set of equations (the Einstein equations) whose solutions are the metrics of a given curved spacetime produced by massive objects such as stars or planets, or other curved spacetimes. Once we use the Einstein equation to find the metric, we can begin to make sense of the way different observers make measurements in that spacetime.

Molecular Volume

See Einstein's doctoral dissertation, no. 7 in [appendix C](#).

Overdetermination and the Unified Field Theory

One of Einstein's notions of what an eventual unified field theory (UFT) might look like was that it would be a classical theory based on field equations fundamentally like those of general relativity (GR). However, it would have certain restrictions on solutions to the equations that would permit only discrete values for many measurable quantities. Classical theories such as GR feature solutions that are continuous. In this way, a particular quantity can have any of the values along a curve defined by that solution. Quantum theories, however, permit only certain discrete values for quantities such as the energy of a photon. How can the classical theory return such discrete values when one expects a continuous function as the solution?

An early response to this question that Einstein entertained was the notion that the field equations might be overdetermined. Normally one has a certain number of variables in a set of equations, and an equal number of equations defining them. In this way, the equations are said to be determined and yield a single continuous solution for each variable. Overdetermined equations contain more equations than unknown variables, so, generally speaking, a continuous function is not possible as a solution. There might be no solution at all, but Einstein hoped that a certain limited number of values might be permitted. Einstein first proposed this view in 1923, at the beginning of his quest for a unified field theory, for which he searched all his life without success.

In the 1930s, Einstein explored the possibility that GR itself might impose very strict limits on the possible solutions. The linearized approximation of GR permits many solutions that one expects from experience with other theories such as electromagnetism. But Einstein's work with Nathan Rosen on gravitational waves, in which they briefly thought they had proven that exact solutions of these waves did not exist in the theory, instilled in him the hope that the full theory would point toward a much more restricted set of possible solutions. He began writing a new paper along similar lines (for which only the draft version survives) before he realized there was an error in his and Rosen's gravitational wave paper that invalidated the proof that gravitational waves did not exist.

A version of these ideas that was inspired by the EPR paper and which lived on after Einstein's death was in the search for a hidden-variables theory of quantum effects. The notion here was that the restriction to certain values in quantum mechanics was actually the result of nature being governed by a classical field theory with certain hidden variables that were not immediately obvious to human observers. These hidden variables prevented many of the solutions that would seem to be permitted by an ordinary field theory. Although hidden-variables theories attracted a lot of attention in the mid-twentieth century, they were eventually shown not to work as originally envisaged.

Photoelectric Effect

When Max Planck introduced his quantum hypothesis in 1900, he seems to have viewed it largely as a trick that, if it represented any physical truth at all, was strictly relevant to the rather specialized conditions of laboratory blackbody experiments involving electromagnetic radiation in a cavity. Although he thought that the atoms in the wall of the cavity were apparently constrained to absorb and emit light energy in small quantum packets, he rejected the notion that the light itself was actually composed of quantum packets. He and other physicists still insisted that light was an electromagnetic wave obeying Maxwell's equations and its energy was determined by the amplitude of the wave. Planck's law relating the energy of individual quanta to the frequency of the light wave (the higher the frequency, the more energy in the individual packets) was only relevant to cavities with standing waves trapped inside and not to general phenomena related to light.

Einstein took the radical step of taking Planck's law seriously and proposing that it applied to light in general. He noticed that in some phenomena only high-frequency light or radiation seemed capable of imparting enough energy to cause a chemical reaction. The most clear-cut case was that of the photoelectric effect, in which light striking the surface of a metal was observed to generate an electric current in the space above the metal. An obvious explanation was that the light provided enough energy to liberate electrons from the body of the metal; they could then flow freely as a current under the right conditions. If this were the case, then, on the classical model, it should follow that if one increased the amplitude or intensity of the light, one should always be able to liberate more electrons and achieve more current flow.

Experiments tended to show, however, that below a certain frequency of light it was impossible to get any current flowing at all, no matter how great the intensity of the light shining on the metal. Einstein's explanation was that a certain minimum energy was required to liberate the electron from the metal. Since the light energy came in quantum packets, according to Planck's law, it followed that the electron had to be struck by a packet with sufficiently high frequency to provide all of this energy. If the frequency of the light fell below a certain value, then the associated energy of the light quantum would be smaller than the minimum required to liberate the electron. Thus, only light greater than a certain frequency could generate a photoelectric current. Einstein realized the daring nature of the proposal, and the prediction was indeed met with skepticism.

In a letter to a friend about his papers of 1905 (his *annus mirabilis*), his paper on the photoelectric effect was the only one he described as revolutionary (see letter to Conrad Habicht, May 18 or 25, 1905, *CPAE*, Vol. 5, Doc. 27; Einstein Archives 12-420).

The great experimentalist Robert Millikan decided to test Einstein's theory. As Millikan later admitted, he was certain that he would prove Einstein wrong. In fact, he proved him precisely correct. In this sense, Einstein's 1905 paper is often

considered the real beginning of the quantum revolution. It was the first confident declaration that fundamental particles might obey a physics different from the classical physics of macroscopic objects.

Photon (Light Quantum)

Einstein was in many ways something of an outsider within the scientific community, especially during the early and late periods of his career. However, the common conception of the scientific outsider, who holds a rejected or controversial idea in lonely isolation for years before final vindication, only rarely applied to him. Both special and general relativity had many important early champions apart from Einstein himself, and although he was genuinely isolated in his pursuit of a unified field theory, his ideas in that area never received any vindication, either before or after his death. Perhaps the idea that best illustrates Einstein the outsider is his concept of the light quantum, what is now called the photon.

Einstein's 1905 paper on the photoelectric effect introduced the notion that light waves travel in quantum packets of energy. Although Planck in his 1900 paper on thermal radiation had proposed that light was emitted and absorbed in quanta, he and other physicists strenuously resisted the idea that light waves traveled as particle-like entities. Since all physicists agreed that light had the characteristic properties of a wave, there was great skepticism at the notion that it also behaved like a particle. The concept of wave-particle duality (*see below*) emerges by stages in Einstein's thought between 1900 and the early 1920s, when it bore fruit in the fairly rapid development of quantum mechanics that took place during that decade, beginning with Louis de Broglie's confident declaration of the wave-particle duality as a fundamental feature of all subatomic phenomena.

Ironically, Einstein did not accept the theory of quantum mechanics that emerged at this time. This rejection came as a considerable shock to his younger colleagues, for whom this new theory seemed the vindication of everything he had been arguing for years.

It is believed that Einstein transmitted his development of the wave-particle concept orally, without committing all of his thoughts to writing. During the 1910s, he began to talk about an interpretation of wave-particle duality in which light was really made up of particles, but particles whose exact positions were unknown. The wave was then a sort of probabilistic guide that told the particle where to go, in a statistical sense. Einstein apparently referred to this accompanying wave as the "ghost field" (*see above*) of the particle. We know this story only from the writings and letters of Einstein's colleagues who referred to this idea, presumably based on verbal discussions with Einstein himself.

There is strong evidence that Einstein's ghost field idea played a central role in the early development of the Born-Heisenberg picture of quantum mechanics. It is no exaggeration to say that Einstein played a central role in the early development of a theory he dramatically failed to endorse and tried repeatedly to subvert or disprove.

The term "photon" was not introduced until the 1920s, when the concept was becoming much more widely accepted. Einstein used the term "light quantum" beginning in his 1905 paper on the photoelectric effect.

Principles of Relativity Theory

Famously, Einstein relied upon four principles in his work on relativity, employing them as axioms from which he logically deduced the main features of the theory. This axiomatic approach to physics is quite unusual. Theories like the electromagnetic field theory were built up by stages in an interplay between observation and deduction. The apparent difference in approach may, however, be due to nothing more than Einstein's extraordinary mastery of the subject, and his ability to draw lessons simultaneously from many apparently disparate fields of physics. Two of the four principles form the foundation of special relativity and the other two were used as guides to the discovery of general relativity. Three of the principles chosen by Einstein were based on well-tested experimental results. He raised these observational results to the status of laws presumed to apply universally, not only in the situations for which they had been tested. He could then construct thought experiments (*see below*) whose hypothetical results he deduced from the principle in order to guide his

development of the overall theory. The fourth principle, Mach's principle, related to a series of well-known observations, but differed from the others in offering a fairly speculative explanation for them. Not surprisingly, there has been considerable debate over the decades as to whether, or to what extent, Mach's principle really is an integral part of general relativity.

PRINCIPLE OF RELATIVITY

The principle of relativity applies to inertial observers, defined as those who are in motion without acceleration. It states that it is impossible for inertial observers to tell if they are in motion without reference to outside bodies. Thus, in a closed room, there is no experiment one can perform that can measure the state of motion of that room, unless the room is undergoing some form of acceleration. One has to have a window through which one can observe the relative motion of outside bodies. For inertial observers, then, there is only relative motion. There is no such thing as absolute inertial motion. The Michelson-Morley experiment was intended to be a way in which, within a closed room, one could detect the motion of the Earth with respect to the invisible sea of the ether, the medium of light propagation. Most physicists, who viewed relativity as a rule that applied to particles, not necessarily to waves, expected the Michelson-Morley experiment to work. Einstein, who had elevated the rule to a principle with very general consequences, regarded its failure as axiomatic.

PRINCIPLE OF THE CONSTANCY OF THE SPEED OF LIGHT

This principle states that all inertial observers will measure light as moving with the same speed through a vacuum, regardless of their own state of motion. This principle combines features of both the emission theory of light (with its light-particle approach) and the wave theory of light. The former states that measurement of light speed is unaffected by one's speed with respect to the medium of light, the latter states that light speed is independent of one's speed relative to the light's source. This principle says that both conditions are true. In 1905, Einstein realized that this principle and the principle of relativity are compatible if one accepts the relativity of simultaneity (*see below*).

PRINCIPLE OF EQUIVALENCE

In 1907, while working in Bern on an article reviewing his special theory of relativity, Einstein had what he described as "the happiest thought of my life" (translated and quoted in Pais, *Subtle Is the Lord*, p. 178). He considered that if someone fell from the roof of a house, then everything that fell with that person would fall at exactly the same rate of acceleration. If the falling person could see only the things falling with him or her, that person might not even be aware that he or she is in motion. The clue that something had changed would be the inability to feel one's own weight. Even if persons had a floor beneath their feet (such as painters might have standing on a platform originally suspended from a roof before the ropes broke), it would produce no force against their feet since the floor would be falling with them at a precisely equal rate. This peculiar feature of the gravitational field, known as free fall, is a consequence of the equality of inertial and gravitational mass. Einstein once again took this well-known physical fact and turned it into an overarching principle. If the simple act of falling could make one feel weightless, it followed that acceleration could cancel out the perceptible effects of the gravitational field. This in turn implied that acceleration and gravity were *equivalent* to each other. A non-inertial observer in a small closed room feeling the effects of acceleration could perform no experiment that would determine whether the room was being accelerated (perhaps inside a rocket ship out in space) or merely on the surface of a planet. Thus, the principle of equivalence could play the same role for non-inertial observers that the principle of equivalence had for inertial ones. Just as the latter had led the way to the special theory of relativity, so the former would be Einstein's guide to a general theory of relativity.

MACH'S PRINCIPLE

Ernst Mach was an Austrian physicist of considerable reputation (the speed of sound is today named after him) and an influential positivist philosopher of science. He was

opposed to the introduction into physics of any hypothetical entities that could not be apprehended by the human senses. This led him, for instance, to oppose the atomic hypothesis. He also disliked the Newtonian concept of absolute space. Newton had proposed a thought experiment, known as Newton's bucket, which pointed out that someone in a closed rotating room would be able to determine his state of motion by observing the surface of water in a bucket, which would be curved because of centrifugal motion associated with the rotational motion of the bucket. Newton pointed out that the bucket, observer, and room were not in motion relative to one another, but an experiment would still show that all were in a state of accelerated (non-inertial) motion, presumably with respect to the background of absolute space. Mach objected that the usual way to tell if one is in a state of rotation is to notice that the universe is swinging around you. You would see the fixed stars as apparently in motion about you. Could it not somehow be that the mysterious centrifugal force in the bucket (sometimes called a fictitious force because there is no apparent source of this force) was actually produced on the water by those fixed stars themselves? Such a force could only be gravity, and Einstein took Mach's idea to be a claim that the inertial properties of matter are caused by the gravitational interactions between each object and all of the other masses in the universe. Because fictitious forces like the Coriolis force are not necessarily radial in direction, Mach's principle led Einstein to anticipate that gravito-magnetic effects (*see above*) like frame-dragging would form part of the theory. In this and other ways, Mach's principle played an important heuristic role in leading Einstein toward the correct theory. However, the theory itself proved not to correspond very closely to Einstein's original conception of Mach's principle, and he eventually concluded that the principle was not, in fact, supported by the theory.

Quantum Mechanics

Quantum mechanics emerged in the mid-1920s, most notably through the work of Werner Heisenberg and Erwin Schrödinger, who discovered the governing equations of the new theory. While it is widely known that Einstein objected to important elements of the new theory, he contributed significantly to its development. In addition to being one of the chief architects of the original quantum theory (which lacked an explanation of the mechanics of quantum particles and instead focused on the creation and absorption of such particles rather than their general motion), he was also the originator of the concept of wave-particle duality (*see below*). The duality concept was fundamental to the development of quantum mechanics and instrumental in the statistics of quantum theory (*see "Bose-Einstein Statistics," above*).

It came as a shock to many physicists, especially Einstein's close friends such as Max Born and Paul Ehrenfest, that Einstein rejected quantum mechanics. It seemed in many ways the culmination of many of the ideas Einstein had introduced or championed in physics. Einstein was the master of the statistical approach to physics, especially emphasizing how the nature of fluctuations (departures from the average in a statistical ensemble of particles) could yield insight into the microscopic world. Ironically, it was the statistical aspect of the new theory that most bothered Einstein. He had always believed strongly that certain aspects of nature arose only in the ensemble (*see "Arrow of Time," above*). Fundamental theories and their equations did not show traces of these statistically based phenomena, such as the arrow of time and the unpredictability of individual fluctuations. The fact that the quantum mechanics included only a probabilistic prediction of the behavior of individual particles meant that, for Einstein, it could not be a truly fundamental theory. He made a number of attempts to show that the theory was incomplete, in that there was a more fundamental theory lying behind it, and he always believed that such a theory would permit separability in physicists' treatment of fundamental particles. Given complete information about a particle, the theory should permit one to analyze its future behavior, independently of other particles (unless it actually collided or interacted with those other particles in the future).

Quantum mechanics, though, insisted that the behavior of many quantum particles was entangled, so that they had to be treated as a statistical whole. Einstein's most cogent criticism of quantum mechanics (in the EPR paradox) attempted to show that this nonseparability of quantum systems was untenable.

Ultimately, although Einstein never became reconciled to quantum mechanics, his efforts to find a classical theory that could supersede it were unsuccessful. (*See also* Unified Field Theory, *below*.)

Radiometer Effect

The radiometer is a small device consisting of several vanes, each silvered on one side, black on the other, inside a partially evacuated glass bulb. The vanes are balanced and arranged so that they rotate when exposed to a source of light or infrared radiation. The device was invented in the mid-nineteenth century by Sir William Crookes and has been the subject of theoretical interest and debate since that time, with many people erroneously believing that the conventional device (often sold as a novelty device, sometimes described as a “light mill”) operates because of radiation pressure against the vanes. Early theorists, such as James Clerk Maxwell and Osborne Reynolds, had argued that the motion was at least partially due to a creep of gas from the cold side of the vanes around the edges of the vanes to the hot side (the dark-colored side, which absorbs light more effectively and heats up in consequence). This effect is known as *thermal transpiration*.

In 1920, Einstein selected this topic as a suitable PhD thesis for his cousin Edith Einstein. She completed her doctorate, under the supervision of Paul Epstein but with considerable input from Einstein himself, in 1922. Einstein was not entirely satisfied with her published paper on the subject, and returned to the topic himself, showing how the effect could be explained as an edge effect. Residual gas molecules striking the hot side of the vane pick up energy and recoil harder than molecules rebounding from the cold side, thus tending to push the vane into motion from the hotter side. However, this effect is counterbalanced—over most of the surface area of the vane and for a relatively soft vacuum—by the fact that incoming air molecules are pushed aside by the more energetic molecules rebounding from the hotter side, thus balancing the forces on the two faces of the vane by permitting fewer molecules to bounce off the hot side.

However, as Einstein showed, at the edges of the plate there are fewer rebounding molecules, so that the net force still pushes on the outer rim of the vane. In combination with Reynolds’s thermal transpiration, this edge effect can push the vanes around at a surprisingly rapid pace. In cases where the vacuum in the bulb is harder and there are fewer gas molecules to interfere with one another, Einstein’s effect can operate over most of the surface of the vanes and can explain the observed phenomenon completely. This was the case that Edith Einstein analyzed in her thesis and paper.

Relativity of Simultaneity

The seminal moment in which Einstein finally overcame the conceptual barriers to a fully relativistic approach to physics came, according to Einstein’s own account, following a visit to his friend Michele Besso in 1905. Having discussed with Besso his frustrations in trying to reconcile his principle of relativity with known experiments on the motion of light, which seemed to suggest that all inertial observers agreed on the velocity of light in a vacuum, Einstein had an insight that not all observers would agree on whether two events taking place at different locations in space happened simultaneously or not.

The reason lay in the finite time it would take any information about distant events to reach observers. If two observers were in motion with respect to each other, but each thought that light traveled at the same speed c , then they would disagree about details of their measurements of distances and times to these distant events. Thus, inertial observers in motion with respect to each other have quite different notions of time and space. Time and space are considered coordinate quantities, parameters that we impose on the events in spacetime that we observe around us, but which are not intrinsic to the fundamental structure of that spacetime. Thus, if a train passes through a small station platform at high speed at 9 o’clock, we mean that two events, the train passing the platform and the hands of the clock inside the station’s waiting room reaching nine, happened simultaneously. Someone on the train, however, may not observe the same coincidence because the light from the clock takes time to catch up with the train, which moves in the time it takes for the light to

travel from the clock to the train. To the observer, the train came through at a slightly later time. It is all the more remarkable that Einstein was able to intuit this astonishing idea since these effects are only observable if one's state of motion is some significant fraction of the speed of light.

Spacetime

The idea of time as a fourth dimension that is comparable, in some respects, to the three dimensions of space predated Einstein and probably owes its origins to the work of nineteenth-century geometers such as Bernhard Riemann. Ironically, Einstein was unfamiliar with Riemann's work when he developed his ideas on the unification of space and time in 1905. (It is ironic because Riemann's work later proved to be central to Einstein's efforts to generalize the special theory he had developed in 1905.)

Einstein's spacetime—modern specialists in the field of relativity write the term as one word—was more than a mere naming convention. His theory of relativity should have been named, in his view, the theory of invariants (he himself only referred to the *principle* of relativity, which underpinned the theory). Invariants are quantities whose value is the same for all observers, no matter what their point of view. Einstein realized that such invariants could only be found by placing space and time on an equal footing as one four-dimensional continuum. Thus, different observers will disagree on the spatial distance between two events (if the two observers are in motion with respect to each other) and on the elapsed time between the events, but they will agree on the spacetime interval between them. The spacetime interval is found using a generalization of Pythagoras's theorem, such that the square of the interval is equal to the square of the spatial distance minus the square of the temporal interval (see "Metric," *above*).

In this way, the vector of spatial displacement—indicating the direction and distance from one point in space to another—is replaced by the four-vector of spacetime displacement from one event in spacetime to another. Similarly, other vectorial quantities, such as velocity and momentum, are replaced by four-vectors that are invariant. Energy and ordinary three-momentum are not invariant quantities in Einstein's theory, but the four-vector combining three-momentum with the energy quantity in the time slot of the four-vector is invariant. Invariants are found by the correct construction of four-dimensional entities.

Shortly after Einstein proposed his theory, Hermann Minkowski presented a formal mathematical version of it that solidified the picture of this new spacetime. Initially skeptical, Einstein had within a few years come to see how Minkowski had shown the way toward a new general theory of relativity. Now it would not only be possible to describe how different observers can measure different quantities in the same spacetime, but also to describe spacetimes with different geometries caused by the gravity produced by massive bodies.

Specific Heat Capacity

The study of the specific heat capacities of various materials was a major scientific industry in the nineteenth century and played an important, if ambiguous, role in the development of thermodynamics. On the one hand, there was considerable success in showing that many materials obeyed simple general rules that agreed well with the predictions of classical statistical physics. For instance, Pierre Dulong and Alexis Petit were able to show that solids generally had the same specific heat capacity that initially appeared independent of the material's temperature. Monatomic gases also seemed to be easy to understand theoretically, whereas diatomic gases displayed a troubling sensitivity to temperature.

At high temperatures, diatomic gases had the heat capacity predicted by theory, but at lower temperatures they behaved as if they were monatomic. Studies by Heinrich Weber (see [Part I](#), Teachers) showed that solids had a somewhat similar temperature-dependent feature. At high temperatures, they behaved as expected and as most other solids behaved according to the Dulong-Petit law. At lower temperatures, however, their specific heats steadily decreased, leading the German chemist Walther Nernst to speculate that the specific heats of all substances might tend toward zero at the absolute zero of temperature. Einstein first solved this

conundrum and showed how Max Planck's quantum principle could explain the mysterious temperature dependence of specific heat capacities.

The classical expectation was that the equipartition theorem (*see above*) applied to all situations where one added energy to a system composed of many atoms or molecules. This theorem demanded that the new energy would be shared equally among all possible degrees of freedom. Einstein observed that the quantum law demanded a certain minimum amount of energy (one quantum of energy) to excite a state of motion associated with a given degree of freedom. If, at low temperatures, the amount of energy available (by the demands of the equipartition theorem) for a given degree of freedom is below this minimum, then the state will remain unexcited. Since Planck's law provides that the size of a quantum be related to the frequency of the excited state, it follows that certain states—the higher frequency ones—are lost before others as the temperature declines.

In the case of a diatomic molecule, vibrational energy states tend to be lost first, followed by rotational states, until the molecule, at lower temperatures, behaves as if it were monatomic. In the case of solids, Einstein showed clearly how classical statistics, modified by his clarification of the equipartition theorem, could explain the way in which Weber had shown specific heat capacities declining with temperature. This work of Einstein's led Nernst to a clear formulation of what became the third law of thermodynamics and convinced many that the quantum law had to be taken seriously, and that it held wide implications throughout physics. It also played a role in the founding of the Solvay Conferences.

Third Law of Thermodynamics

The third law of thermodynamics was developed during Einstein's early career and, to a great extent, as a result of his contributions. It was largely the brainchild of Walther Nernst, the German physical chemist, who was one of the young Einstein's first admirers. Nernst's early ideas about the third law arose from the observation that the specific heat capacity of many solids begins to decrease consistently as their temperature gets colder. In other words, these solids were losing the ability to absorb heat. It seemed likely to Nernst that as the temperature reached absolute zero, the solids would lose the ability to absorb heat altogether. There was, however, no understanding of the reason why this process should take place. In fact, the classical theory of specific heats was unable to explain this behavior.

The theory that existed was based on the equipartition theorem (*see above*). It states that when heat is available to a system with multiple degrees of freedom, the heat will be equally divided up (or partitioned) among those degrees. Thus, if the molecules of a gas are free to move forward-backward, left-right, and up-down and also to rotate in place, the available heat energy, which is nothing more than the kinetic energy of motion of the individual molecules, will be divided equally among these four kinds of motion. Thus, on average the molecules are as likely to move faster in any of the three directions, and are equally likely to rotate faster in response to an addition of heat. It seemed inexplicable that the molecules would somehow lose the ability to move altogether as the temperature decreased.

In 1907, Einstein applied the ideas behind Max Planck's quantum hypothesis to the problem of specific heats (*see above*) of solids at low temperatures. Planck's original insight had been that the problem of the blackbody spectrum could be explained if energy was emitted or absorbed only in little packets, called quanta, and that the size of a packet was proportional to the frequency associated with the energy (*see "Blackbody Radiation," above*). Thus, as Einstein had also observed in his explanation of the photoelectric effect, the quantum theory was biased against higher-frequency states.

If the equipartition demanded that all the available energy be divided equally among all the possible states or degrees of freedom, what would happen if the amounts available to a state were less than one quantum? In that case, this state would not be excited at all. Einstein realized that the vibrational modes of energy of the individual atoms in a solid constituted many states. At high energies (thus at high temperatures), the amount of energy available permitted many states, even quite high-frequency ones, to be excited. Yet as temperatures dropped, the total energy available became smaller and smaller after dividing among all of the atoms and their vibrational modes. This meant that fewer and fewer of the higher-frequency

vibrations could be excited, as the average energy available fell below one quantum. Thus, Einstein's quantum theory predicted that the solids' ability to absorb heat continually would decrease with decreasing temperature.

Based on this clearer theoretical picture, Nernst proposed that this effect might be true of all materials and might thus constitute a third law of thermodynamics.

Later, in the 1920s, Einstein was able to use his new law of quantum statistics (known as Bose-Einstein statistics; *see above*) to show that gases would also lose their specific heat capacity as the temperature dropped, providing the final theoretical underpinning of the new law.

Time

During his struggles to formulate a new theory of what came to be known as special relativity, Einstein developed a radically new understanding of time. Instead of being a universal progression that was experienced as an identical, if mysterious, phenomenon by all observers, Einstein understood time to be nothing more than the term applied to a series of coincidences between observed events. Thus, when we say that the train arrived on time at 9 o'clock, we mean that two events occurred simultaneously, one event being the arrival of the train at the station platform, the other being the moment when the hands on the station clock reached the position indicating 9 o'clock.

Clocks are merely devices that produce a periodic series of events that provide convenient labels for measuring the occurrence, and the order of occurrence, of less predictable events. This understanding laid the groundwork for Einstein's fundamental breakthrough in developing the theory of relativity, the idea that observers in different states of motion might disagree as to whether certain events really happened simultaneously.

This "relativity of simultaneity" (*see above*) permitted time to be understood in a truly relativistic fashion. As with space, time had no independent existence outside of our observation and measurement of the behavior of observable physical objects. These events made up the actual structure of spacetime, which could not exist without them.

Time Dilation

The clear understanding of the role time played in a relativistic theory of physics that Einstein achieved in mid-1905 permitted him to realize that observers would not only measure the length of a moving object to be different from that of the same object at rest (this had already been incorporated into the electron theory of H. A. Lorentz), but also that observers would see physical processes associated with the moving object as being slowed down with respect to the same physical processes observed in the stationary object. This wholly unexpected phenomenon, based on the relativity of spacetime and not just of space, became known as time dilation.

Einstein's other insight was in realizing that effects such as time dilation were not a physical effect that happened to bodies that were in motion. Rather, they were artifacts of measurement that occurred when the measurer was in motion relative to the thing measured. Thus, as long as both objects were in inertial (constant velocity, unaccelerated) motion, it was irrelevant whether the measurer was moving and the thing measured was at rest, or the thing measured was moving and the measurer was at rest. In both cases, clocks, and any physical process aboard the measured object, would appear to be slower than in the case where the measurer and the object measured were motionless with respect to each other. Thus, two inertial observers in motion with respect to each other would each claim that their own clocks were fine, but that the other's clock was running slow.

Examples of physical processes that would be slowed in this way include the emission of light waves. The light waves would have a color associated with the frequency of the emitting process. Once the emitting body is set into motion, observers will see this process slowed, so that the frequency (the running rate of the process) is reduced. Accordingly, the light emitted is also reduced in frequency, becoming redder. It was well known that objects emitting light were redshifted as they receded from an observer and blueshifted as they approached, called the "Doppler effect" or "Doppler shift." The Einstein redshift associated with time dilation

could be observed even if the emitting object was moving neither toward nor away from the observer but in a transverse direction. It was thus often known as the “transverse Doppler shift.”

Since the process of aging is a physical mechanism that acts as a kind of clock, it follows that two inertial observers in motion with respect to each other would each think the other was aging more slowly (because each would think the other was the one in motion). What would happen if the two observers could return to meet each other? This question formed the substance of the twin paradox. The short answer is that the observer who was at rest with respect to the remainder of the universe would be the one who had aged more.

Wave-Particle Duality

One of the most revolutionary aspects of quantum mechanics is the resolution of the long-standing dichotomy between wave and particle in favor of the notion that physical phenomena partake of the characteristics of both, an idea known as wave-particle duality. This crucial idea was formulated just in advance of quantum mechanics and laid the groundwork for the whole theory. The clear formulation of the notion that subatomic entities are both particle and wave was the culmination of the old quantum theory and the foundation of the new quantum mechanics. Although the concept of wave-particle duality, as it was formulated in the mid-1920s, has several fathers (including Louis de Broglie, Werner Heisenberg, Erwin Schrödinger, Max Born, and Niels Bohr), it can be fairly argued that Einstein was the man first on the scene to advocate this radical proposal, something that all the others acknowledged.

Debates about whether light was composed of waves or particles had been common since the time of Newton, who had advocated the particle view. In the early nineteenth century, the evidence in favor of the wave nature of light became overwhelming, and by Einstein’s time the question was regarded as unanswerable. No one believed any longer that light was composed of particles, and certainly no one was considering the counterintuitive idea that light might be composed of both waves and particles.

Einstein’s 1905 work on the photoelectric effect naturally raised the idea that light had qualities both of particle and wave. There were, indeed, several ways in which Einstein thought of light as particulate, not only in the quantum theory. Even in the classical theory his ideas on relativity inclined toward the emission theory of light, usually associated with the particulate model. Nevertheless, he certainly accepted the success of the wave theory and its modern formulation in Maxwell’s theory, of which he was a master. With typical clear-sightedness, he confronted directly the contradiction in his own position and began to argue that the light quantum (what we would now call a photon) behaved like a particle, while also behaving as part of a wave.

In the 1910s, Einstein began to speak of the ghost field (*Gespensterfeld*; see above). If light was really composed of particles, what was the nature of the wavelike aspect of the electromagnetic field? According to colleagues like H. A. Lorentz and Born, Einstein proposed that the wave was a probability function that guided the motion of the particle of light. This ghost field did not carry the energy of the field, which resided only in the particles, but the ghost fields of the different quantum particles interfered with one another in a wavelike manner. Since the particles could not go where interference completely destroyed the ghost field, the result was wavelike properties of light, such as interference and diffraction. Einstein never published this idea, but he discussed it with close colleagues, and his thinking seems to have been very influential in the development of the interpretation of quantum mechanics by Born, Heisenberg, and Bohr.

For more than a decade, Einstein was a lone voice advocating the idea that light had a dual nature. Then, in the mid-1920s, in a very Einsteinian step, physicists took the argument the other way, reversing the logic. Whereas Einstein had argued that light, once thought to be a wave, was also a particle, now the argument was being made, by Louis de Broglie, that particles, such as the electron, could assume a wavelike nature.

Doctoral Dissertation

See no. 7 in [appendix C](#).

Influential Scientific Forebears and Contemporaries

Einstein's earliest scientific and technological influences came from within his family: his father and uncle owned and operated businesses in the emerging field of electricity generation and transmission. Many of us are familiar with the story of the compass that his father gave him at an early age, and the impression it made on him about unseen forces in the world. As an adolescent, he tried his hand at various technical problems in the family's factory shops, which gave him invaluable practical grounding in electrical technology. No later than his early teens, he became an avid reader, consuming a series of volumes on popular science by Aaron Bernstein (*Naturwissenschaftliche Volksbücher*), a study of the natural properties of force and matter (*Kraft und Stoff*) that illustrated the scientific materialism of Ludwig Büchner, and Alexander von Humboldt's *Kosmos*, a five-volume treatise on science and nature.

As a university student, Einstein was disappointed in the traditional physics fare offered at the Swiss Federal Polytechnical School (ETH) and embarked on a course of independent study to learn firsthand from the masters. He was particularly attracted to the kinetic theory of matter (*see* Kinetic Theory, *below*) and to the works of James Clerk Maxwell and Ludwig Boltzmann, who had founded his field of interest. Since Maxwell's work on electromagnetism played a central role in his other great scientific interest—relativity—we can fairly say that the Scotsman was the greatest single influence on Einstein's thinking. Besides Boltzmann and Paul Drude, who introduced Einstein to Maxwell's contributions in German, he read assiduously in this period the writings of Hermann von Helmholtz, Heinrich Hertz, Gustav Robert Kirchhoff, Wilhelm Ostwald, and Max Planck. He was also conscious of a debt he owed to even earlier men of science such as Isaac Newton: "Newton, ... the concepts which you created are even today still guiding our thinking in physics, even though we now know that they will have to be replaced," he mused in his "Autobiographical Notes" (pp. 31–33).

A scientist whose philosophy of science left its indelible mark on him was the positivist Ernst Mach (*see* Philosophy of Science, *below*). While attending the Swiss Federal Polytechnical School (ETH) in Zurich, Einstein had read and admired Mach's historical-critical studies on mechanics and thermodynamics, which as he wrote in Mach's eulogy "had greatly influenced our generation of natural scientists" ("Ernst Mach," March 14, 1916, *CPAE*, Vol. 6, Doc. 29). Soon after graduation, however, Einstein came to reject Mach's skepticism of the atomic hypothesis that was based on the older man's refusal to introduce into physics entities that could not be perceived by the senses. Einstein went on to make the major contribution to the final acceptance of the existence of atoms.

Mach's opposition to the idea of space as an entity that existed apart from matter proved more fruitful and influenced Einstein in his search for a theory of general relativity. Like his mentor, Einstein felt that space was not a preexisting container into which material objects could be placed. Rather, space was merely the name given to the measured relationships between material objects. If you take away matter, space would simply cease to exist. Although Einstein firmly believed in this aspect of Mach's thought and it lay at the heart of his efforts to overthrow the doctrine of the luminiferous ether, in later years he came to believe that his early enthusiasm for Mach was a mistake. He concluded that the theory of general relativity did ultimately treat space as something that had an existence of its own.

Einstein's path to special relativity a decade earlier was, by his own account, heavily influenced by his reading of David Hume's *A Treatise of Human Nature*, Part One: *Of the Understanding*. He had studied it in the Olympia Academy in Bern "enthusiastically and with admiration shortly before the discovery [in 1905].... It is very well possible that without these philosophical studies [Hume and Mach] I would not have arrived at the solution" (letter to Moritz Schlick, December 14, 1915, *CPAE*, Vol. 8, Doc. 165; Einstein Archives 21-610).

Henri Poincaré, too, influenced Einstein's thinking on relativity. As with Hume, Einstein had read the first volume of Poincaré's collected essays as part of the "curriculum" in the Olympia Academy (see [Part III](#), Organizational Ties). It is likely that Poincaré's views as expressed therein encouraged Einstein to reject the ether, clearly enunciate the relativity principle, and comprehend that the measurement of time was not absolute. Having no ready access to Poincaré's papers that had not been published in this volume of essays, Einstein was not aware of the Frenchman's own work in relativity. (See also Galison, *Einstein's Clocks and Poincaré's Maps*.)

The importance of Kant's influence is assessed in the section on Philosophy of Science; for that of H. A. Lorentz and Max Planck, see *Colleagues*.

Kinetic Theory

The kinetic theory of matter proposes that all matter is composed of atoms that obey the same fundamental laws of motion and are so numerous that their overall behavior can be determined statistically to a near perfect degree of probability. The classical kinetic theory was developed during the late eighteenth and early nineteenth centuries and reached its mature form in the late nineteenth-century work of James Clerk Maxwell and Ludwig Boltzmann. In this form, the laws obeyed by the individual particles were the Newtonian laws of mechanics, and the statistics was the classical statistics of distinguishable particles (that is to say, it was assumed that the motion of each particle could, in principle, be so accurately tracked that we would always know which particle was which). The chief objective of the kinetic program was to show that the gross properties of matter, as understood in the field of thermodynamics, could be derived from kinetic principles.

Einstein began his scientific career as a specialist in the kinetic theory of matter. He was a master of the Maxwell-Boltzmann theory, and his early papers extended this theory in various ways. These early papers were enough to attract some favorable attention for Einstein, but not lasting fame; unknown to him, most of his work had been anticipated by the great American theorist Josiah Willard Gibbs. Einstein was fully aware of the controversy surrounding the kinetic theory. A number of prominent physicists were opposed to the kinetic theory and the atomistic hypothesis. Boltzmann had even committed suicide, partly in despair at the hostile reception his work received. Nevertheless, in 1905 Einstein boldly took an approach in direct contrast to the one that had previously characterized the field. Instead of trying to show how the kinetic theory perfectly matched the predictions of thermodynamics—there were so many atoms that one could never observe the fluctuations, which is to say, the departures from the most probable outcome—Einstein searched for those rare situations where the fluctuations (see *Concepts*) were sufficiently prominent to be noticeable. This was the topic of his paper on Brownian motion (see *Concepts*). Einstein later wondered why no one before him had done this. In his Brownian motion work, Einstein was more fortunate than he had been earlier in his kinetic-theory career, since he managed to have his new fluctuations-based approach to the problem published a year earlier than the Polish physicist Marian Smoluchowski.

The controversy over the existence of atoms (see *Concepts*) was largely ended, to a great degree as a result of Einstein's early work. During 1905, he presented new ways of determining Avogadro's number: the number of atoms in one mole of a substance, in his thesis on molecular volumes (see *Doctoral Dissertation*, no. 7 in [appendix C](#)) and in his paper on Brownian motion. This is another way of saying that he helped establish quantitatively the size of atoms, a giant step on the road to their acceptance as part of the worldview of physics. Now, the outlook of opponents of the atomic hypothesis such as Ernst Mach is usually depicted as being rather silly; however, there was a serious side to their objections. Mach, as a positivist, opposed introducing into physics entities that were outside the sensory experience of physicists.

Einstein agreed with Mach on this concept when it came to the luminiferous ether. We can understand Mach's point more sympathetically when we consider that there was no way in which the physicists of 1900 could know that Newton's laws of mechanics actually applied to atoms (or to subatomic particles such as electrons, which had only recently been discovered). It was an assumption that the laws derived for the mechanics of macroscopic bodies also applied to microscopic bodies. That assumption turned out to be wrong. Eventually, a whole new theory of mechanics—

quantum mechanics (*see Concepts*)—had to be derived to describe the behavior of electrons. Ironically, Einstein did refuse to accept the implications of this new theory of mechanics because of its violent clash with the principles of classical mechanics, so in a sense Mach had the last laugh. Indeed, even the classical theory of statistics does not apply to electrons, because they are indistinguishable particles. (In quantum mechanics we are forced to accept the fact that it is not possible, even in principle, to be certain which electron is which as they move past one another.) Einstein recognized this problem and formulated a new quantum theory of statistics in his work with the Indian physicist Satyendra Bose (*see Concepts*, “Bose-Einstein Statistics”).

Einstein’s mastery of the kinetic theory included a deep insight into the role played by the equipartition theorem (*see Concepts*), which states that the energy available to the atoms and molecules will be distributed evenly among them and among the various directions and ways in which they might move. Although the equipartition theorem had been applied successfully to a wide variety of situations, there were a number of problems in kinetic theory that Einstein came to understand had the same underlying issue: the equipartition theorem no longer applied because of Planck’s quantum law. Using this insight he was able to explain the mysterious way in which the specific heat capacities of materials decreased with temperature and help give birth to the third law of thermodynamics. His statistical approach to physics also played into his thinking about the origin of time. (*See Concepts* for more on the above topics.) He believed strongly that the arrow of time, the unidirectional flow of time, came about solely because of statistical considerations. Thus, if the universe contained only a few particles, time could flow backward as easily as forward. (*See also Brush, Statistical Physics.*)

Lectures, Major Scientific

(Numbers refer to the listing in [appendix C](#), where summaries are given.)

Published Lectures

Princeton University, 1922. The Stafford Little Lectures, “Four Lectures on the Theory of Relativity, Held at Princeton University in May 1921.” *See* no. 97.

Kyoto, December 14, 1922. “How I Created the Theory of Relativity.” Not to be confused with his other, unpublished public lecture in Kyoto on December 10. *See* no. 101.

Nobel Prize Lecture, Göteborg (Gothenburg), Sweden, 1923. “Fundamental Ideas and Problems of the Theory of Relativity.” *See* no. 106.

California Institute of Technology, 1931. “Science and Happiness.” *See* no. 129.

Herbert Spencer Lecture, Oxford University, 1933. “On the Method of Theoretical Physics.” *See* no. 146.

George A. Gibson Foundation Lecture, Glasgow University, 1933. “Notes on the Origin of the General Theory of Relativity.” *See* no. 148.

Unpublished Lectures

Keio University, Tokyo, 1922. “Overview of Special and General Relativity—The Special and General Principles of My Relativity Theory.” Although this lecture was attended by more than two thousand people in the Mita Grand Lecture Hall, later destroyed during the war, it was never published.

Rhodes Lectures, Oxford, May 1931. “Theory of Relativity: Its Formal Content and Its Present Problems.” These lectures were never published because, according to Einstein, they were “in too fluid a state” for publication (*see Schilpp, Albert Einstein*, p. 722).

Josiah Willard Gibbs Lecture, Carnegie Tech, Pittsburgh, 1934. Delivered to the American Association for the Advancement of Science. “Elementary Derivation of the Equivalence of Mass and Energy.” A German abstract of the lecture is in Einstein Archives 1-123.

Nobel Prize

As is well known, in 1895 Swedish inventor Alfred Nobel of dynamite fame established the prize bearing his name. It is the most prestigious international award given to groundbreakers in a number of specific cultural and scientific fields. The process that leads to the award is discharged by the Nobel Committee of the Swedish Academy of Sciences, which invites experts in their particular fields to nominate candidates. After studying the merits of each submission, the committee chooses the recipient and submits its recommendations in a report to the Swedish academy, giving the reasons for its choices. The academy as a whole votes up or down on the recommendations, or it can choose someone entirely different as long as there is a majority opinion. The awards are sometimes shared by more than one person, especially in the sciences. The first prizes were awarded in December 1901.

Einstein was nominated for the prize nine times before he was chosen as the laureate in physics for 1921:

- 1910, nominated by Wilhelm Ostwald (the 1909 chemistry laureate)
- 1912, nominated by Ostwald, Ernst Pringsheim, Wilhelm Wien (the 1911 laureate), and Clemens Schaefer
- 1913, nominated by Ostwald, Wien, and Bernhard Naunyn
- 1914, nominated by Naunyn and Orest Chwolson
- 1916, nominated by Felix Ehrenhaft
- 1917, nominated by Arthur Haas, Emil Warburg, and Pierre Weiss
- 1918, nominated by Ehrenhaft, Warburg, Wien, Max von Laue (the 1914 laureate), Edgar Meyer, and Stefan Meyer
- 1919, nominated by Warburg, von Laue, E. Myer, Max Planck (the 1918 laureate), and Svante Arrhenius (the 1903 chemistry laureate)
- 1920, nominated by Warburg, along with six others, including H. A. Lorentz (the 1902 laureate)
- 1921, nominated by Planck, Warburg, and Haas, and a growing list of many others.

The most often cited reason for the delay of the award to Einstein is that members of the academy were not able to judge relativity competently, yet the pressure to give him the honor grew each year because of his many other accomplishments. Skeptics still abounded even after the general relativity tests of 1919. The committee finally decided to propose him to the academy instead “for his services to theoretical physics and especially for his discovery of the law of the photoelectric effect,” which for the first time had applied quantum theory to systems other than pure radiation. The academy approved the recommendation.

Einstein was in the Far East when he received the news, though he makes no mention of it in his travel diary (*see* [Part I](#), *Travels and Travel Diaries*).

The 1921 award was deferred to 1922, the year for which Niels Bohr received the prize, and was not presented to Einstein until the summer of 1923, when he went to Gothenburg, Sweden, to deliver the required Nobel lecture. Even though the award was not given specifically for relativity theory (although the phrase “for his contributions to theoretical physics” might include that work), he decided to speak about it in his lectures. He gave one lecture to a large general audience of about two thousand people, including King Gustav V of Sweden, on “basic ideas and problems of the theory of relativity,” and a more technical one to a smaller audience of fifty who were interested in the finer details of the theory.

Sources: Pais, “*Subtle Is the Lord*”; Elzinga, *Einstein’s Nobel Prize*; Nobel Foundation website.

Patents and Inventions

Einstein worked in the Swiss Patent Office from 1902 until 1909. His area of specialty was in electric and electromechanical devices, with which he had gained some familiarity in his family’s business (*see* *Influential Scientific Forebears* and

Contemporaries, *above*). He seems to have been effective in that role, and even after he took up positions in academia he was still in demand as an expert witness in patent trials. One of these involved the gyroscopic compass patent held by German industrialist Hermann Anschütz-Kaempfe and contested by Sperry, an American company. Einstein appeared as a witness for Anschütz-Kaempfe several times and at one point even considered taking a position with his company. He later contributed to some of Anschütz-Kaempfe's subsequent designs.

Einstein kept up his nearly lifelong interest in patents by also taking out his own. Perhaps the best known is a patent for a new, silent form of refrigeration on which he worked with physicist Leo Szilard (*see Collaborators*). They designed two cooling systems, a gas-cooled refrigerator and a pump to operate it, but their idea was never realized commercially. Together, Einstein and Szilard applied for more than a dozen patents in several countries, almost all of which were granted. Other devices for which Einstein obtained patents include the magnetostrictive sound reproduction mechanism for a bone-conduction hearing aid (developed with Rudolf Goldschmidt; *see Collaborators*) and the moveable automatic diaphragm for a camera (with Gustav Bucky; *see Collaborators*).

See József Illy, *The Practical Einstein*, for these and more of Einstein's patents and experimental tinkerings. *See also* Dannen, "The Einstein-Szilard Refrigerators," and Lanouette and Silard, *Genius in the Shadows*, for Einstein's work with Leo Szilard. *See also* Scientific Sidelights, *below*, and [Part I](#), Myths and Misconceptions, "Was Only a Theorist."

Philosophy of Science (contributed by Thomas Ryckman, Stanford University)

Einstein was not a philosopher in any familiar sense but a physicist, and at most a "philosopher-scientist" (Schilpp, *Albert Einstein: Philosopher-Scientist*). The numerous remarks of a principally philosophical character among his writings reflect the perspective of success as a theoretical physicist, above all, with the general theory of relativity. Philosophers typically develop their views in dialogue with, or in response to, those of other philosophers or traditions, as did Kant responding to Hume and Leibniz to empiricism and rationalism. But almost without exception, from the 1920s until his death in 1955, Einstein broached philosophical issues in science with a highly specific professional interest in mind. Faced by the late 1920s with the challenge of the quantum theory and what he perceived to be its guiding philosophy of positivism, he sought to motivate and systematically elaborate a deeply rooted opposing conviction regarding the nature of physical theory, and so the very aim of scientific inquiry.

While his philosophical pronouncements do reflect the influence of decades of philosophical reading, a guiding conception of the meaning and significance of physical theory shaped his philosophy of science rather than the other way around; as he once put it, "the [physicist] himself knows best ... where the [philosophical] shoe pinches." As a result, Einstein's philosophy of science cannot be assimilated to any antecedent philosophical *-ism*; Einstein himself admitted that, to the "systematic epistemologist," he must seem an "unscrupulous opportunist," his philosophy a *mélange* of the *realist*, the *idealist*, the *positivist*, and inasmuch as Einstein elevated "logical simplicity" as an effective criterion of theory-choice, as the "*Platonist* or *Pythagorean*" (Schilpp, *Albert Einstein*, p. 684).

The most extensive articulations of Einstein philosophy of science occur in a 1935 essay, "Physics and Reality," and in material written in 1946, appearing in the 1949 Schilpp volume. In the latter, responding in his "Replies to Criticisms" to the then orthodox understanding of the quantum-mechanical wave function that forbade consideration of unmeasured physical quantities, Einstein pronounced this positivist attitude to scarcely differ from Berkeley's *esse est percipi*. Yet while impugning Berkeley's subjective idealism as absurd, Einstein was prompted to give a more palatable, though still suspiciously idealist, elucidation of how to understand the posits of physical theory:

“Being” [*Das ‘Sein’*] is always something which is mentally constructed by us [*von uns gedanklich Konstruiertes*], that is, something which we freely posit [*Gesetztes*] (in the logical sense). The justification of such constructs [*Setzungen*] does not lie in their derivation from what is given to the senses. Never and nowhere is there a derivation of this kind (in the sense of logical deducibility), not even in the domain of prescientific thought. The justification of the constructs that represent the “real” [*das ‘Reale’*] for us lies solely in their more perfect, or less imperfect, suitability for making intelligible what is sensorily given (the vague character of this expression is forced here upon me by my striving for brevity). (Schilpp, *Albert Einstein*, p. 669)

Brevity has not served Einstein well. For instance, presumably with his well-known objection to the quantum theory (that it is incomplete) foremost in mind, he often has been, and continues to be, regarded as the paradigm Realist. What then is the significance of the fact that Einstein consistently placed the term “real” or “physical reality” in scare quotes? How can the Realist consider “existence” or “being” to be an “intellectual construction”? And, anyway, what is meant by “free supposition”?

A fully satisfying answer to these questions would have to come to terms with Einstein’s understanding of the character of physical theory, an understanding instructed by the axiomatic (or “principle”) structure of the two theories of relativity but as well informed by philosophical discussions of precisely this topic by late nineteenth and early twentieth-century theoreticians of classical physics, especially Helmholtz, Hertz, Boltzmann, Lorentz, Planck, Poincaré, and Duhem. Such an answer cannot be attempted here. It is nonetheless possible to indicate the more salient tendencies in the above remarks. Helmholtz, Hertz, and Planck, the latter two both students of Helmholtz, underscored the broadly Kantian idea that to the extent that physical reality is knowable, it is a “construction” of (or is “constituted by”) the intellect; a few pages later, Einstein similarly paraphrased the “truly valuable” in Kant as consisting in the message that “there is a conceptual construction [*begriffliche Konstruktion*] for the comprehension of the interpersonal whose authority lies solely in its confirmation [*Bewährung*]. This conceptual construction refers precisely to the ‘real’ [*‘Wirkliche’*] (by definition), and every further question concerning the ‘nature of the real’ appears empty” (Schilpp, *Albert Einstein*, p. 680).

Poincaré’s conventionalism stressed above all the limits of empiricism, in particular that the axioms of geometry could by no means be uniquely determined by measurements of spatial distances and angles but were “freely chosen” conventions, the criterion of choice being “simplicity” or convenience. Hertz, Planck, and especially Duhem placed emphasis on the methodological fact that the relation of empirical observation to theoretical posit was often indirect, and physical theories are accordingly hypothetico-deductively tested as a “whole,” by deriving from theoretical postulates consequences that lead to empirical predictions. Boltzmann and Planck argued against positivism that the aim of physical theory is a “grasp” of the Real, despite an inevitable (and to Planck, sobering) recognition that this goal cannot knowingly be attained. At the turn of the century, H. A. Lorentz, whom Einstein deeply admired, essentially articulated Einstein’s 1919 distinction between “theories of principle” (like the theories of relativity) and “constructive theories” (theories such as the kinetic theory of gases, which attempt to explain the observed phenomena by constructing them from fundamentally simple laws and assumptions). To these tendencies Einstein, most notably in his June 1933 Herbert Spencer Lecture at Oxford, added a distinctive and characteristic touch that continues to influence fundamental physical theory: that mathematical speculation, guided by considerations of symmetry and aesthetics, can be a mode of discovery. It is instructive, however, that Einstein referred to this rationalist impulse as “tempered,” and was aware of his own failures with unified field theory, as akin to the quest of Don Quixote (*see* letter to Michele Besso, April 15, 1950; Einstein Archives 7-396).

Quantum Theory

By his own admission, Einstein devoted more time to thinking about the problems of quantum theory than to any other area of physics. That he is not more commonly associated with the quantum is the fault of his very public opposition to aspects of quantum mechanics, as it emerged in the mid-1920s. Yet the old quantum theory that preceded it was in great part Einstein's work, much more than is true of any other physicist.

The quantum theory began with Max Planck's (*see Colleagues*) work on the theoretical determination of the blackbody spectrum (*see Concepts*). Previous efforts to explain the spectrum of thermal radiation given off by black bodies (those bodies that only emit thermal radiation) had encountered a problem in explaining the high-frequency end of the spectrum, as it was observed in the laboratory. Planck solved this problem in what seemed to be a somewhat ad hoc way. He proposed that electromagnetic waves, when they took the form of standing waves trapped in a cavity between material walls, could only have energies expressed in quanta, or packets, such that the size of each packet was proportional to the frequency of the radiation. Thus, instead of being continuous, radiant energy (at least in this special circumstance) came in discrete packets. Since the packets were larger at higher frequencies, the quantum effects showed themselves only when applied to high-frequency radiation. Thus, Planck was able to explain why classical theory had no difficulty explaining the lower-frequency end of the blackbody spectrum, but that only his quantum hypothesis could explain the high-frequency end.

Einstein took the radical step of taking Planck's quantum hypothesis seriously. He proposed that if it applied in the special case of a standing wave in a cavity, there was no reason why it should not also be true of electromagnetic radiation in general. He first did this in 1905 while examining the photoelectric effect (*see Concepts*). He recognized that this study of the electric currents that were generated when light fell on a metal surface was another instance in which light behaved contrary to what would be expected of continuous phenomena. It was observed in studies of the photoelectric effect that, below a certain frequency, light lacked the ability to generate a current at all when falling on a given metal. Einstein observed that this was difficult to explain if light was absorbed continuously, as one would expect of a wave train. Even if a certain amount of energy was required to liberate an electron from its atom to generate a current, if the energy built up continuously over time one would merely have to wait for enough energy to be absorbed for the current to begin flowing. Instead, the current always began as soon as the light reached the metal, or not at all if the light was below a certain critical frequency. This phenomenon suggested that the electrons absorbed the light in the quantum packets proposed by Planck. Thus, they received all the energy they needed in one lump or not at all. If the radiant quanta carried too little energy to liberate an electron, they would never be able to do so; and if they did, then no waiting period was required.

Einstein began searching for other areas where the old kinetic theory (*see above*) based on statistical physics, of which he was a master, was encountering difficulties. He found one in the study of the specific heat capacities of substances (*see Concepts*). It had been observed experimentally that some materials began losing the ability to absorb heat as temperatures got lower. Einstein realized that this was another way in which a classical theory, here the equipartition theorem (*see Concepts*), began to break down as one entered the quantum regime. The equipartition theorem, which underpins the kinetic theory, insists that energy is equally shared among all possible modes in a statistical system. If energy comes in discrete packets, however, then, as the amount of energy available becomes small (as happens at low temperatures), there will be insufficient energy to excite a mode at all. Thus, the higher-frequency modes will be stuck in the ground state, unable to absorb any energy. As the temperature gets even lower, more and more modes will be lost and with them the material's ability to absorb as much heat as it did before. By explaining the observed effect in this way, Einstein neatly opened the door for the articulation of the third law of thermodynamics (*see Concepts*), which states that as the temperature approaches absolute zero, where there is no heat at all, the specific heat capacities of all substances will approach zero.

An obvious objection made to Einstein's version of the quantum theory was that there existed an enormous body of experimental evidence that light really did behave as a wave. Yet here was Einstein returning, in essence, to the old picture of particles of light (which we now call photons) once advocated by Newton. In response,

Einstein began to propose an early form of wave-particle duality. Einstein argued that the wave aspect of light acted as a sort of ghost field, telling the little particle or light quantum where to go in a probabilistic sense. (See Concepts on these topics.)

In attempting to prove one way or the other whether light was emitted as a wave or a particle, Einstein spent the early 1920s searching for an *experimentum crucis*, a critical experiment that could decide the issue. Instead, it led him to a brush with scientific fraud when he put forward experiments to be performed on canal rays by Emil Rupp (see Concepts, “Canal Rays”), a promising young experimenter who, years later, admitted to completely fabricating the results of his experiments. Contemporary historians think it is likely that he also fraudulently performed the experiments requested by Einstein.

Around the same time, Einstein took a final crucial step that married his long-standing interest in statistical physics with his work on the quantum theory. He responded to the work of the Indian physicist Satyendra Bose, sent to him in a personal letter, which showed how to derive Planck’s blackbody radiation law from first principles. Einstein realized, better than Bose himself, that the key step in Bose’s derivation was that he treated all of the particles as indistinguishable. Traditional statistics assumed that it was always possible, in principle, to keep track of each particle individually and therefore know which one was which. The key to quantum statistics is to realize that since the particles are identical and too small to be tracked (obviously so in the case of photons), it follows that one doesn’t know which particle is which at any given moment. This fact has profound implications for statistics. Thus, today we refer to Bose-Einstein statistics (see Concepts) as the statistical method that is used to describe a whole family of elementary particles. These particular particles (called bosons) all have the extraordinary ability to condense into one single unified state at low temperatures. Einstein first recognized this effect after working on Bose’s ideas; it is now known as Bose-Einstein condensate (see Concepts).

By this time, a new generation of younger physicists, inspired by and comfortable with Einstein’s ideas, had developed the mature theory of quantum mechanics (see Concepts). It was a shock and surprise to many when Einstein rejected this new theory, which seemed so much in accord with his own ideas. Ironically, Einstein, the master of statistical physics, objected to a major result of quantum mechanics: that in many cases it was impossible to separate the fate of particles whose wave functions were combined. Einstein ultimately believed in a classical picture that maintained it should always be possible, at least in principle, to study a system as if it were composed of fundamentally independent particles whose future fates were separable from one another. He attempted to undermine the new theory via a clever series of thought experiments, many of which were proposed at the Solvay Conferences (see below) and cleverly answered, favorably for the new theory, by Einstein’s friend and colleague Niels Bohr.

Einstein’s final response to this dialogue was the famous Einstein-Podolsky-Rosen (EPR) paradox (see Concepts) proposed in the mid-1930s. Here he presented his most daring indictment of entanglement (where two particles have a combined wave function), showing how it demanded the existence of a certain type of action-at-a-distance (see Concepts) that violated the relativistic principle that information cannot be transmitted at greater speed than the speed of light. Although the EPR paper did not ultimately lead to a challenge to the quantum theory, it did provide the basis of a very fruitful series of theoretical and experimental endeavors in the years since Einstein’s death.

In his later years, Einstein’s chief response to quantum mechanics was to nourish the hope that his efforts to find a unified field theory (see below) would eventually replace it with a fundamentally classical theory that would somehow explain quantum effects. In this hope he was disappointed. Modern attempts at a unified theory take an opposite tack, presuming that the final theory will be quantum in nature and will replace classical theories such as Einstein’s general theory of relativity. (See also Cassidy, *Einstein and Our World*; Kuhn, *Black Body Theory*; and Whitaker, *Einstein, Bohr, and the Quantum Dilemma*.)

Relativity Theory

Special Relativity

This theory is arguably Einstein's single greatest contribution to physics. Though he received the Nobel Prize for his work on the quantum theory and owed his worldwide fame to the success of his general theory of relativity, Einstein's two 1905 papers on special relativity have had a greater influence on every aspect of twentieth-century physics than any other comparable piece of work he produced.

There was a growing awareness in the first years of the twentieth century that the problem of relative motion as it pertained to electrodynamics needed to be examined. Important theorists such as H. A. Lorentz and Henri Poincaré had taken a number of critical steps in this direction. Lorentz had found a set of transformation relations (named after him) that could permit theorists to take a set of physical equations worked out in one "reference frame" and transform them into a valid set of equations for another such frame. These reference frames were understood to be a mathematical expression of the different measurements or observations that might be made by two different observers who were in motion with respect to each other. He had also shown that an object in motion might be shorter than the same object at rest, due to its motion with respect to the electromagnetic field (see Concepts, "Length Contraction," also known as Lorentz length contraction). Poincaré had realized that these issues were associated with subtle problems of what we mean by measurement, and what issues are raised if we take into account the fact that measurement of a quantity like length naturally involved a process of receiving information from another location in space. If this information must travel at a finite speed to reach us, there are implications for the process of measurement itself.

Yet it was Einstein who realized that what appeared to be a number of interesting quirks in the study of electrodynamics actually had revolutionary implications for the study of kinematics, one of the fundamental topics of modern physics. Indeed, one reason why no one had conducted such a study before Einstein was that most physicists were content to ignore such foundational issues—they were too well settled to bother thinking about them. For instance, although it was understood that the electrodynamic theory derived from Maxwell's systems of equations did not obey the same transformation relations of relative motion used in Newtonian mechanics, this fact did not trouble many physicists. Their expectation was that since electromagnetism was a theory describing wavelike phenomena, it was natural enough to think that the theory of relativity, worked out to deal with particle or projectile motion, did not apply to it.

This understanding of the difference between relativity of particles and relativity of waves meant that many physicists expected that an experiment, such as the one conducted by Michelson-Morley (see "Experimental Tests of Special Relativity," *below*), should be able to determine the speed of the Earth through the ether. They were surprised when the attempt failed. Conversely, Einstein, a convinced relativist, believed in a stronger version of relativity than other physicists did. He believed that it ought to be impossible to do an experiment on Earth, without looking at objects outside the Earth, to determine Earth's state of motion. This is Einstein's principle of relativity. He would have expected the Michelson-Morley experiment to fail because it violated this principle. Although it is often said that this experiment had a great influence on Einstein, it actually played little role in his thinking as he tried to develop special relativity. Once he accepted his relativity principle, the Michelson-Morley experiment's failure was totally expected and explained little more than that the principle was probably correct. Einstein's problem was to show how this principle was compatible with other physical experiments and theories.

The problem Einstein faced was that, in relativity theory, light did not seem to behave either like a wave or like a particle. If it behaved like a particle, one would expect that light emitted by a fast-moving star (such as in a binary star system) would move faster than light emitted by a stationary star. If it behaved like a wave, then the Michelson-Morley result would be expected, since the Earth ought to be moving with respect to the medium of the wave (the luminiferous ether, in whose existence Maxwellians believed). Neither expectation was supported by experiment. This led Einstein to his second principle—the principle of the constancy of the speed of light.

Determining how to reconcile these two principles with the known experimental results forced Einstein, like Poincaré before him, to seriously consider the problem of

time (*see Concepts*). Most physicists have presumed that measurements of the time elapsed between two events by different observers would always agree. Einstein came to the realization one day that evidence showing that two events in different places happen simultaneously must await the arrival of news about those events. That news must be “brought” by the light (electromagnetic) waves that are themselves the object being studied. Einstein realized that his two principles could be reconciled if one correctly understood the relativity of simultaneity (*see Concepts*). Different observers might disagree on whether two events really took place at the same time. As a result, different observers might disagree on their measurement of the time elapsed between two events (*see Concepts*, “Time Dilation”).

This situation might seem to have left the whole problem in a hopeless mess. Everything was relative, no measurements could be relied upon. Einstein realized, however, that quantities did remain that were invariant, in the sense that all observers would measure them to have the same value. Measurements of neither space nor time individually, however, could be invariant. Only by unifying these two concepts into the single entity of spacetime (*see Concepts*), and only by measuring spacetime intervals between events rather than by distances and times, could one find invariants. Einstein felt these invariants were so fundamental to the theory that he was disappointed that physicists settled on the term “theory of relativity” for the whole theory. He had originally spoken only of the *principle* of relativity. Had he chosen a name for the theory as a whole, he later claimed, he would have named it the “theory of invariants.”

After making the conceptual breakthrough embodied in the relativity of simultaneity, Einstein was able to publish the full theory very quickly (since he had spent years contemplating the problem already). Within a short time of completing that first paper, he realized that there was one more important result implied by the new theory. Just as a moving object would appear foreshortened to a stationary observer (length contraction) and its clocks would appear to be running slowly relative to those of the stationary observer, so such an object would appear to be more massive than it was when at rest. The reason was that it would have more energy (because it was in motion and therefore had kinetic energy), and Einstein realized that energy produced inertia and therefore had mass. He thus introduced the famous equation $E = mc^2$ (*see Concepts*). This equation, undoubtedly the most famous in all of physics, illustrates the importance of the theory. (*See also Stachel, Einstein's Miraculous Year; Martínez, Kinematics.*)

EXPERIMENTAL TESTS OF SPECIAL RELATIVITY

Certain experimental results are known to have played an important role in leading Einstein toward the theory he published in 1905. Among these are Hippolyte Fizeau's experiments on the speed of light in moving water and the astronomical study of stellar aberration. He was also influenced by Michael Faraday's law of induction, in particular the fact that it does not matter if one moves the magnet or the coil of wire in which the current will be induced; the result is still the same, suggesting that only relative, not absolute, motion mattered for this effect. However, the experiment that, in hindsight, was considered by many people to have anticipated Einstein's theory, the Michelson-Morley experiment, hardly figured at all in Einstein's thinking. Only occasionally in later years did he even speak as if he had been aware of this experiment while working on his theory. Essentially, it provided additional proof of something about which he was already convinced: that the principle of relativity applied to all physical effects in nature.

In the decade after Einstein published his theory of special relativity, the majority of physicists, especially those interested in testing it experimentally, regarded it as being a version of H. A. Lorentz's theory of electromagnetism. Thus, early attempts at experimental verification or falsification focused on the Einstein-Lorentz theory. The main rival theory was Max Abraham's theory of the electron (*see Rivals, below*). The best-known early experiments were those of Walter Kaufmann, which essentially tested the formula $E = mc^2$ by attempting to measure the mass of electrons at different speeds. Kaufmann's results of 1905 claimed to agree with Abraham's theory rather than Einstein's, but Max Planck reanalyzed Kaufmann's results and cast doubt on this conclusion. Einstein does not seem to have been much perturbed by the apparent setback.

By 1915, a number of other experimenters had performed similar tests, all of which agreed with Einstein. These experiments were difficult and their results open to challenge, but details of the fine structure of the spectral lines of hydrogen were in quite close agreement with calculations made on the basis of Einstein's mass-energy formula.

The prediction of special relativity that was unique to Einstein's work was the phenomenon of time dilation. However, sufficiently precise clocks were not available until some decades after Einstein's prediction of the effect in 1905. The Ives-Stillwell experiment of 1938 is generally regarded as the first verification of this prediction. Today a number of technical systems, such as the Global Positioning System (GPS), must take account of time dilation, or the transverse Doppler shift, as it is also known. In general, time dilation is a feature of special relativity that has had relatively few successful tests devoted to it, but many important results of contemporary physics depend upon the presumption that it is correct.

General Relativity

Einstein's theory of special relativity (*see section above*) had been given a favorable reception in the physics community. By 1907, he was asked to write a review article summarizing the state of research in this area. He took the opportunity to discuss the possibility of a general theory of relativity as the next logical step in the theory's development. The principles upon which the special theory was based, and the results derived from them, were restricted to the case of inertial observers, that is, observers in a state of motion with constant velocity and no acceleration. As long as one dealt only with such observers, the transformation relations (Lorentz transforms) of special relativity could show how to convert the physical equations relevant to one inertial observer into the equations valid for a different inertial observer. Obviously, these observers, both being inertial, would be moving with respect to each other in a straight line at constant speed. Einstein believed it was possible to achieve general covariance, so that even if observers were accelerating with respect to each other, it would be possible to find transformation relations (generally applicable) that could allow one to convert the correct equations used for one into the valid equations for the other.

It is a testament to Einstein's belief in an especially expansive notion of relativity that he would even think such a theory would be possible to construct. Most physicists did not believe that accelerated observers experienced the world in the same way as other observers and therefore did not expect that general covariance, even if it were possible, would be especially useful. In writing his review article, however, Einstein had an insight that he later described as "the happiest thought of my life" (*see no. 89 in [appendix C](#), and the discussion in Pais, "Subtle Is the Lord," ch. 9*). He realized that the equivalence principle provided a set of observers with whom accelerated observers could be properly compared. Those observers were standing in a gravitational field (for instance, on the surface of a planet). So, while the principle of relativity indicated which observers could be compared productively in the special case of unaccelerated motion, the principle of equivalence identified more general classes of observers who could be successfully compared to each other. The principle of equivalence would thus replace the principle of relativity in the search for a general theory. Inevitably, the general theory of relativity also would be a new field theory of gravity.

Not only would the principle of relativity not apply to the general theory (because it applies only to inertial observers), but also the second underlying principle (or axiom) of special relativity theory: the principle of the constancy of the speed of light, following Ernst Mach (*see Influential Scientific Forebears*) applies only to inertial observers. Accelerated observers, or those in a gravitational field, do not necessarily measure the speed of light in a vacuum to be c . Einstein, in need of a second principle for the general theory, adopted what he termed Mach's principle-, which he phrased as a sort of corollary to the equivalence principle. It was well known that a person in a rotating (spinning) frame of reference experienced certain forces (centrifugal force, Coriolis force) that were unknown to inertial observers. Einstein proposed that these forces were somehow produced by the gravitational field of the mass of the entire universe. Since the Coriolis force is a tangential, not a radial, force, Einstein therefore anticipated from the beginning that his new theory of gravity would exhibit what we

now call gravito-magnetic effects (*see Concepts*) such as frame-dragging, which resemble the behavior of the magnetic field in Maxwell's theory of electrodynamics.

Already in 1907, Einstein realized that the equivalence principle itself permitted certain predictions of special relativity to be extended to the study of gravity. If being in a gravitational field was equivalent to being in a state of accelerated motion, it followed that an observer outside of the field would see the clocks in the gravitational field running slowly (*see Concepts*, "Time Dilation"). The suspicion naturally arises that they would also see spatial distances altered (*see Concepts*, "Length Contraction"), but in what sense? By considering the case of the rotating disk in special relativity (*see Concepts*, "Ehrenfest's Paradox"), Einstein reached the conclusion that acceleration and gravity do indeed distort spatial dimensions, since the ratio of circumference to diameter of the rotating disk is no longer equal to π .

Note, at this point, that there is an important distinction between special and general relativity. In special relativity, the inertial observers all claim that it is the other person who is "really" moving. They themselves are at rest. Thus, each inertial observer thinks it is the other inertial observer who has slowly running clocks and shrunk meter sticks. But in general relativity, everyone agrees who is really accelerated or who is really in a gravitational field. Therefore, they agree on whose clock runs slowly and whose space is distorted. It follows, then, that the distortions of space and time in general relativity cannot be transformed away merely by changing coordinate systems. The distortions of general relativity are no trick of measurement, or a mere artifact of one's point of view. They are objectively real distortions of space and time. Einstein realized that gravity alters the metric of spacetime (*see Concepts* for both).

In special relativity, where measurements of distances and times differ depending on one's point of view, we nevertheless find that spacetime intervals are always derived from those distances and times using the same rules of Pythagoras's theorem. In general relativity, however, when gravity is present, the spacetime is no longer flat, and a modified form of Pythagoras's theorem is needed. This modification of how measurements of space and time go together to define spacetime intervals is expressed by the metric of spacetime and is due to the curvature (departure from flatness) of that spacetime.

By 1912, Einstein had realized that he needed a four-dimensional metric theory of gravity based on geometry in curved spacetime. Not an expert in advanced mathematics, he asked his friend Marcel Grossmann (*see Part I, Friends*) for help. Grossmann quickly pointed him toward Riemannian geometry. Together the two men labored to find field equations for general relativity that would give expression to general covariance while at the same time yielding the known results of Newtonian gravity for the solar system. They failed.

Einstein developed the hole argument (*see Concepts*) to explain their failure and abandoned the quest for general covariance. He and Grossmann published the *Entwurf*, or outline, theory of gravity in 1913. Two years later Einstein paid a visit to the University of Göttingen, where he discussed his ideas extensively with the mathematician David Hilbert (*see Colleagues*). Hilbert convinced him that general covariance was a noble and achievable goal (something that was not at all clear to most physicists). Einstein discarded the *Entwurf* theory and soon, in November 1915, found the right field equations.

The confirming result was his discovery that not only did the (now fully covariant) theory have the correct Newtonian limit, but in one case—the perihelion shift of Mercury; *see* "Experimental Tests of General Relativity," *below*—it differed from Newton by exactly the amount astronomers insisted was correct. Einstein had considered this as an experimental test of the new theory from the beginning, but refrained from mentioning it in print until he was sure his theory could pass the test.

Over the succeeding few years, Einstein exploited the new theory to found two entirely new fields of physics (*see Concepts*, "Cosmology," "Gravitational Waves"), modifying it where necessary (*see Concepts*, "Cosmological Constant"). Experimentally, the theory passed the two remaining tests he had identified. The eclipse test (famously associated with the British astrophysicist Arthur Stanley Eddington) achieved a level of publicity that made Einstein world famous and cemented his reputation as the greatest physicist since Newton. (*See also Eisenstaedt, The Curious History of Relativity*; Janssen and Renn, "Untying the Knot"; Norton, "How Einstein Found His Field Equations"; and Renn and Schulmann, *Albert Einstein, Mileva*

Marić: *The Love Letters*.)

EXPERIMENTAL TESTS OF GENERAL RELATIVITY

Einstein is sometimes portrayed as having been indifferent to the experimental verification of his theories. There exists a famous story that, upon showing a doctoral student the telegram bringing him news of the results of the 1919 eclipse test, he was asked how he would have felt if the theory was falsified and responded: “I would have had to pity our dear God. The theory is correct all the same” (Ilse Rosenthal-Schneider, *Reality and Scientific Truth*, p. 74). (See also [Part I](#), Myths and Misconceptions, “Verification of General Relativity Theory Was Unimportant to Einstein.”) Stories such as this may do nothing more than show that Einstein was amused by—and played up to—the burgeoning myth of the cocksure theorist. At an earlier stage of the theory’s development, he had striven mightily to entice astronomers into making the observations that would test his theory.

The experimental verification of general relativity presented challenges comparable to those that faced testers of the special theory. The general theory differed most strongly from the predictions of Newtonian theory when velocities were a significant fraction of the speed of light and when the gravitational field was particularly intense, each of them difficult conditions to satisfy. Einstein recognized that the immediate vicinity of the Sun was the likeliest arena for a successful test and that therefore he would need to appeal to astronomers for verification. Already in 1907, he had proposed two feasible tests for the theory: one on the measurement of a gravitational redshift of spectral lines in solar light, and another on the gravitational deflection of starlight passing close to the Sun. In both cases, the measurements involved would be close to the limit of detectability. In the latter case, they would be complicated by the need to make the observations during an eclipse, the only time when stars close to the Sun would be visible; and in the former case, by competing effects, such as a Doppler shift due to rising and falling gases in the solar atmosphere.

Upon determining that astronomers were initially unenthused about putting his ideas to the test, Einstein found a young German astronomer, Erwin Finlay Freundlich, who was willing to take up the challenge. Einstein raised money to enable Freundlich to lead an expedition to the Crimea to test the light-bending prediction at the eclipse of August 1914. Unluckily, the First World War erupted just in advance of the eclipse, leading to Freundlich’s internment by the Russians as an enemy alien. The world war and Germany’s defeat prevented Freundlich from attempting any further eclipse work until after the celebrated English eclipse expedition of 1919 (see [Colleagues](#), “Arthur Stanley Eddington,” *above*). He did attempt to observe the eclipse of 1922 but was clouded out. Ironically, although he tested the theory at eclipses in later years, he had by then had a falling-out with Einstein. Freundlich was a prickly customer who feuded with a number of his colleagues, and Einstein appears to have grown tired of this rancor. Perhaps as a result of the cooling of his relationship with Einstein, Freundlich became convinced that his later eclipse measurements did not agree with general relativity, but his views proved unconvincing to his fellow astronomers.

In addition to being involved in the eclipse testing, Freundlich also worked on the solar redshift test. Then, after the Einstein Tower, a solar observatory, was completed in 1924 in Potsdam, near Berlin (see [Part I](#), Fame, “Art and Commercialism”), Freundlich became its director until he fled Germany to escape the Nazis.

Possibly even more significant for the eventual happy conclusion of the redshift test was the work of two physicists based in Bonn, Leonhard Grebe and Albert Bachem. Einstein encouraged them to tackle this problem in an effort to counteract the skepticism toward relativity that solar astronomers expressed. Their efforts did help point the way toward the eventual solution, most prominently articulated by the American solar astronomer Charles Everard St. John. It explained the redshift of spectral lines in the Sun as being a complex superposition of two different effects: the Doppler shifting caused by rising and falling columns of gas in the solar atmosphere, and Einstein’s gravitational redshift caused by the intense gravitational field of the Sun.

It seems likely that privately Einstein had also set as an early goal the explanation of the most famous anomaly in astronomy at that time, the perihelion advance of Mercury, which had defied all attempts at explanation within the existing Newtonian

gravitational theory. Thus there were three classical tests of general relativity, as several decades went by before other tests became practical.

The first of the three tests passed by the new theory was the perihelion advance of Mercury. This was demonstrated by calculations carried out immediately after Einstein found the final form of his field equations in November 1915. Nineteenth-century astronomers had measured the tiny amount of this anomaly in Mercury's orbit so well as to permit a very precise agreement with Einstein's calculation. Einstein was able to show that Mercury's orbit did not form a closed ellipse because the Sun's gravitational field distorted spacetime. In the altered geometry close to the Sun, there was insufficient room for Mercury to orbit quite like the other planets. This was convincing confirmation that spacetime really was curved in the presence of a strong gravitational field.

For the second test, astronomers had noticed a small and variable redshift in spectral lines observed in sunlight before Einstein drew attention to it. Although this shift was about the size predicted by Einstein's theory, the fact that it varied between different spectral lines and different locations on the surface of the Sun seemed to be in conflict with Einstein's prediction.

The third test, the deflection of starlight, was the decisive test. The confirmation of the theory by the British eclipse expedition of 1919 encouraged astronomers to reinterpret existing solar redshift data in ways that tended to confirm the theory, and also urged them to obtain new data, both from the Sun and from the white dwarf stars, which seemed to offer further confirmation. (See also *CPAE*, Vol. 9, pp. xxxi–xlii, for a thorough discussion of the path to the confirmation of general relativity; and Crelinsten, *Einstein's Jury*.)

These three successful classical tests, which propelled Einstein to world fame, remained the only tests until the 1950s. New discoveries in physics and astronomy began to make further tests possible then, beginning with the Pound-Rebka experiment, which finally and unambiguously demonstrated the gravitational redshift in the 1950s. In the 1970s, many more accurate light deflection observations became possible by radio astronomy observations of quasars being occulted by the Sun. New tests emerged, including the Shapiro time delay, made possible by space travel, and the discovery of the binary pulsar PSR 1913+16 in 1974. Among other things, the latter proved the existence of gravitational waves (*see Concepts*), one of the more novel predictions of Einstein's general relativity theory.

The success of Einstein in overthrowing Newton's theory of gravity encouraged others to follow suit, and dozens of alternative theories of gravity have been generated. One of the main goals of theory-testing experiments since the 1950s has been to test these theories—the best known is the Brans-Dicke theory—against relativity. As of the early twenty-first century, general relativity has passed all such tests. All other theories either have failed one or more tests or have been forced into conforming so closely to the predictions of GR as to be indistinguishable from the theory at the current level of sensitivity. Even the Global Positioning System (GPS) has to take the theory into account—specifically, gravitational time dilation—in order to operate correctly. (*See also* Crelinsten, *Einstein's Jury*; Earman and Glymour, "Relativity and Eclipses," and "The Gravitational Redshift as a Test of General Relativity"; Hentschel, "Einstein's Attitude towards Experiments," and *The Einstein Tower*; and Will, *Was Einstein Right?* and *Theory and Experiment in Gravitational Physics*.)

Anti-Relativity Campaign

In 1920, a series of events took place that were directed against Einstein and relativity theory. They were thinly veiled anti-Semitic attacks instigated by physicist Philipp Lenard and right-wing publicist Paul Weyland, who accused Einstein of having "a particular press, a particular congregation" that took it upon itself to promote Einstein as something more than he was. Indeed, some of the articles written about him in the press, often written by Jews, were hyperbolic in their descriptions of Einstein and his work. To Einstein, however, they were more of an irritant than a chance to indulge in publicity for himself, which he was known to detest. On August 24, the first of a lecture series intended to expose Einstein as a propagandist and fraud took place at the Berlin Philharmonic Hall. The two speakers, Weyland and spectroscopist Ernst Gehrcke, did their best to discredit Einstein and his work.

Einstein, who was in the audience, responded on August 27, with an article in the newspaper *Berliner Tageblatt*. In it, he denounced their campaign, refuted the assertions of the speakers point by point, and documented the acceptance of his theories by the most respected physicists. Still, he was rattled enough to consider leaving Germany, and received offers to work in other countries.

After the event, support and expressions of outrage came from scientists and other admirers in Germany, who urged him to stay in Berlin and continue fighting the anti-relativists. Only one more lecture of the proposed twenty took place, and Weyland's efforts did not have much support from the scientific community. Einstein decided to remain in Berlin, feeling the campaign against him was collapsing, and he supported continuing discussions of relativity theory among scientists. (See no. 84 in [appendix C](#); see also Rowe, "Einstein's Allies and Enemies," and Wazeck and Koby, *Einstein's Opponents*.)

Rivals

While a few great scientists were involved in infamous rivalries and controversies with fellow scientists during their careers (Isaac Newton being an especially prominent example), Einstein was not. It is perhaps characteristic of his personality that he is better known for his scientific friendships (with figures like Niels Bohr, Max Born, and Paul Ehrenfest) than for his rivalries. Nevertheless, he was not a saintly figure who was unable to harbor ill-feelings toward others. He could, on occasion, experience some glee at the thought of interpersonal conflict, and he did genuinely dislike some people. But he was largely free of envy and was well-disposed toward those who shared his enthusiasm for physics, whatever their disagreement.

Arguably, Einstein's only career rival was the brilliant physicist Max Abraham, a man of his own generation who shared a similar background (both were German Jews who waited many years to obtain academic positions in Germany) and worked in similar fields. Abraham began his career under more fortunate circumstances than Einstein. He was a student of Max Planck and came to prominence for his theory of the electron, which was the chief rival of Einstein's special relativity theory for a number of years. Indeed, early experiments at first seemed to favor Abraham's theory. Lorentz, whose work agreed with Einstein's (their theories were regarded, for the purposes of electrodynamics, as identical), despaired, but Einstein, displaying his usual sang-froid, predicted that the experiments would eventually favor him, which they did (see Relativity Theory, "Special Relativity—Experimental Tests of Special Relativity," *above*). Subsequently, Abraham tackled the problem of producing a relativistic theory of gravity to replace Newton's theory. This once again put him in direct competition with Einstein, and, once again, his theory was totally eclipsed by the success of general relativity. Although fate had put the two men on parallel paths and made them rivals in theoretical work, Einstein held fast to nothing more than his absolute conviction that his theories were right and Abraham's were wrong.

Abraham spent years abroad in Italy before returning to Germany during the First World War. He finally found a permanent position in Germany some time after the war ended, only to learn, before he could even begin the new job, that he had a brain tumor, from which he died shortly afterwards.

The only man involved in anything resembling a priority dispute with Einstein was his colleague, the mathematician David Hilbert. The reader should not be surprised, however, that his name is included in the section on colleagues in this volume because the appearance of a dispute between the two is due more to the efforts of contemporary historians than to any animosity between Einstein and Hilbert themselves.

A more serious opponent, if not a rival, was Philipp Lenard, a fellow physicist in Germany who knew Einstein well but turned against him, motivated by political differences and nationalist sentiments. In this case, Lenard's feelings for Einstein were reciprocated. In spite of their aversion to each other, Lenard is included in this volume under the section on colleagues. Though Lenard devoted enormous time and effort to finding others who, he claimed, had greater priority than Einstein to several of Einstein's discoveries, he could make no such claims for himself. All the men whose names he invoked were dead and in no position to object to their role as Einstein's proxy rivals. They included the Prussian astronomer Johann Georg von Soldner (who published a formula similar to Einstein's for the deflection of light by the Sun's

gravity; *see* Relativity Theory, “General Relativity: Experimental Tests of General Relativity”); the Austrian physicist Friedrich Hasenöhl (who derived the famous $E = mc^2$ formula in a restricted case and was killed in action during the First World War); and a German physics teacher, Paul Gerber (who more or less accidentally produced a formula similar to Einstein’s prediction for the perihelion advance of Mercury; *see* Relativity Theory, “General Relativity: Experimental Tests of General Relativity”).

For the remainder of Einstein’s career, most of his rivals in physics were men who lacked the stature to challenge his work in any meaningful way. Among those who tried was Edouard Guillaume, an old colleague from Einstein’s days in the patent office in Bern. He should not be confused with his relative Charles-Edouard Guillaume, a Swiss inventor who was awarded the Nobel Prize the year before Einstein. The Guillaume with whom Einstein was friendly became determined to oppose relativity theory, especially in the period after the publication of general relativity (though his objections were related more to the special theory). Einstein devoted a long correspondence to patiently trying to explain to Guillaume that his arguments against the theory were invalid. Guillaume’s objections were based on his failure to properly comprehend the theory, as was the case with so many other anti-relativists. Friedrich Adler, with whom Einstein was very friendly (*see* Colleagues), also tried to show that relativity was incorrect.

A much more knowledgeable and fiercer critic of Einstein’s work was the prominent Polish-American physicist Ludwik Silberstein. Although his textbooks on relativity helped to greatly popularize the theory in the United States, he also became interested in attempts to overthrow it experimentally. In the 1930s, he engaged Einstein in a debate over the theory, arguing that the two ends of the Einstein-Rosen bridge were two separate particles whose failure to move closer to each other violated what we know about gravity. In fact, the bridge forms a single geometrical structure in spacetime whose ends would appear, to outside observers, to be in two different regions (*see* no. 157 in [appendix C](#)). Silberstein, who became annoyed at the lack of engagement with his arguments by fellow physicists, reacted by rallying the press to become interested in his attempts to discredit Einstein’s theory. But, in the end, both Silberstein and Guillaume withdrew their claims, and Einstein continued to treat them in the same friendly way as before.

One of Einstein’s only rivals with regard to a unified field theory was Erwin Schrödinger, the discoverer of wave mechanics. Einstein and Schrödinger had known each other well during Einstein’s last years in Berlin. From the thirties on, both men were interested in unification and carried on a correspondence on the topic. However, in 1947, after both had already left Germany, they exchanged barbs in the press over Schrödinger’s claim to have developed a theory using an approach previously tried by his older colleague. Einstein was nettled by Schrödinger’s willingness to let the press portray him as succeeding where Einstein had failed. The episode seems to have done some damage to their cordial relations, and did nothing to advance the search for unification in physics.

The assortment of cranks and political opponents who made up a great part of the anti-relativity movement do not count as Einstein’s rivals in any professional way.

Scientific Papers

See [appendix C](#).

Scientific Sidelights

Einstein began his career as an expert in the kinetic theory of matter and made a name for himself with his work on relativity and quantum theory. However, his interests in science were even more wide-ranging and comprehensive than these accomplishments imply, and many other subjects caught his interest over the course of his long career. These ranged from superconductivity, which he tried unsuccessfully several times to explain theoretically, to the meanders of rivers, for which he tried to explain the alleged fact that rivers in the Northern Hemisphere erode their right banks more than their left. Although it is impossible to give an exhaustive list of such work, one can endeavor to give some sense of the breadth of

his oeuvre.

Some of his side interests were well within his known areas of research but were not strongly connected to his most famous works in those areas. An example is his paper on the radiometer effect (*see Concepts*), clearly related to his original love of the kinetic theory but a topic that, unlike Brownian motion, never came to be seen as critically relevant to bigger questions.

Einstein greatly enjoyed being involved with experimental or practical matters. He was able to draw on his considerable experience from his work in the Swiss patent office analyzing technical designs. He often jumped at the chance to be involved in experiments, especially with a collaborator. His best-known foray into experimental work was his collaboration with Wander de Haas (*see Collaborators*), which led to the discovery of the Einstein-De Haas effect. Often it was not possible for him to work in the laboratory himself, but he would make suggestions by corresponding with an experimenter to achieve modifications of the experimental apparatus to reach a desired result. Examples of this sort of collaboration include his work with Emil Rupp and Auguste Piccard (*see Collaborators*).

His interest in these sidelights was often related to one of his more profound programs but ended up not being particularly relevant. Such an example is his work on canal rays (*see Concepts*) with Rupp, which was intended to be an *experimentum crucis* as to the precise quantum nature of photon emission. Similarly, his 1936 paper with Nathan Rosen that introduced the geometrical spacetime construction known as the Einstein-Rosen bridge (*see Concepts*), or wormhole, was intended by Einstein as a possible model of how an elementary particle might be constructed out of pure spacetime (it therefore is related to his unified field theory program; *see below*). Instead, it became one of the most entertaining and science-fictional entities in the catalog of solutions of the Einstein equations, being nowadays strongly associated with the possibility of time travel.

An analogous case was Einstein's collaboration with Piccard, which investigated an idea from Einstein's youth. Late nineteenth-century attempts to unify the electric and gravitational fields included the proposal that there is an imbalance between the attractive and repulsive forces of the electromagnetic field. Thus, two neutral bodies would actually produce, say, a net attractive force that, as was originally hoped, would prove to be a gravitational force. By the 1920s, this idea was no longer considered viable, but Einstein proposed to revive it to explain another anomaly of physics, the Earth's magnetic field. It is very difficult to explain why the Earth should have a persistent magnetic field, since even though such fields could be produced by current motions in the core of the Earth, the fields should always act to damp down the very motion that produced them. Einstein pointed out that the imbalance idea could not be damped out and the imbalance could be very small and still explain the magnetic field of an object as large as the Earth. Piccard, in correspondence with Einstein, conducted very sensitive experiments to show that the imbalance did not exist at the level required. Although Einstein remained interested in possible neutral currents in the Earth's core as an explanation of geomagnetism, his ideas proved fruitless in this case. Our modern explanation relies on a complex model of the geodynamo in which multiple current loops produce fields that reinforce one another's motions.

Early in his career, Einstein displayed little interest in astronomy. Years later, when that field provided the means by which his theory of general relativity was vindicated (*see Relativity Theory*, "General Relativity—Experimental Tests of General Relativity"), he even admitted to a colleague, "How we are helped here by the pedantic precision of astronomy, which I often secretly poked fun at" (letter to Arnold Sommerfeld, December 9, 1915, *CPAE*, Vol. 8, Doc. 161; Einstein Archives 21-383.1).

As work on general relativity compelled him to search for astronomical tests of the theory, however, he naturally became knowledgeable about certain astronomical problems. Wondering if the theory could be tested on a much greater distance scale than that of the solar system, he became interested in globular clusters, objects containing thousands of stars that orbit the center of our galaxy. Although they never proved to be a useful testing ground for the cosmological aspects of general relativity (*see Concepts*, "Cosmology"), he nevertheless published on them. Looking for the anomalies and disagreements between Newtonian theory and measurements of solar system motions, he was one of the first people to suggest that some anomalies, noticeable chiefly in the complex motion of the Moon (*fig. 40*), might simply occur

because the length of the day is not constant. It is now known that glitches in the rotation of the inner core of the Earth can slow down the rotation of the crust, which was misinterpreted by astronomers as a change in the rate of motion of nearby objects; however, it was only because our main astronomical clock had simply lost a second or two.

Finally, the paper on gravitational lensing that he reluctantly published at the urging of Rudi Mandl (*see Collaborators*) served, in spite of Einstein's low expectations for it, as the foundation for a major field of modern astronomy that has helped astronomers see farther into space and farther back in time than was ever imagined possible during Einstein's lifetime.

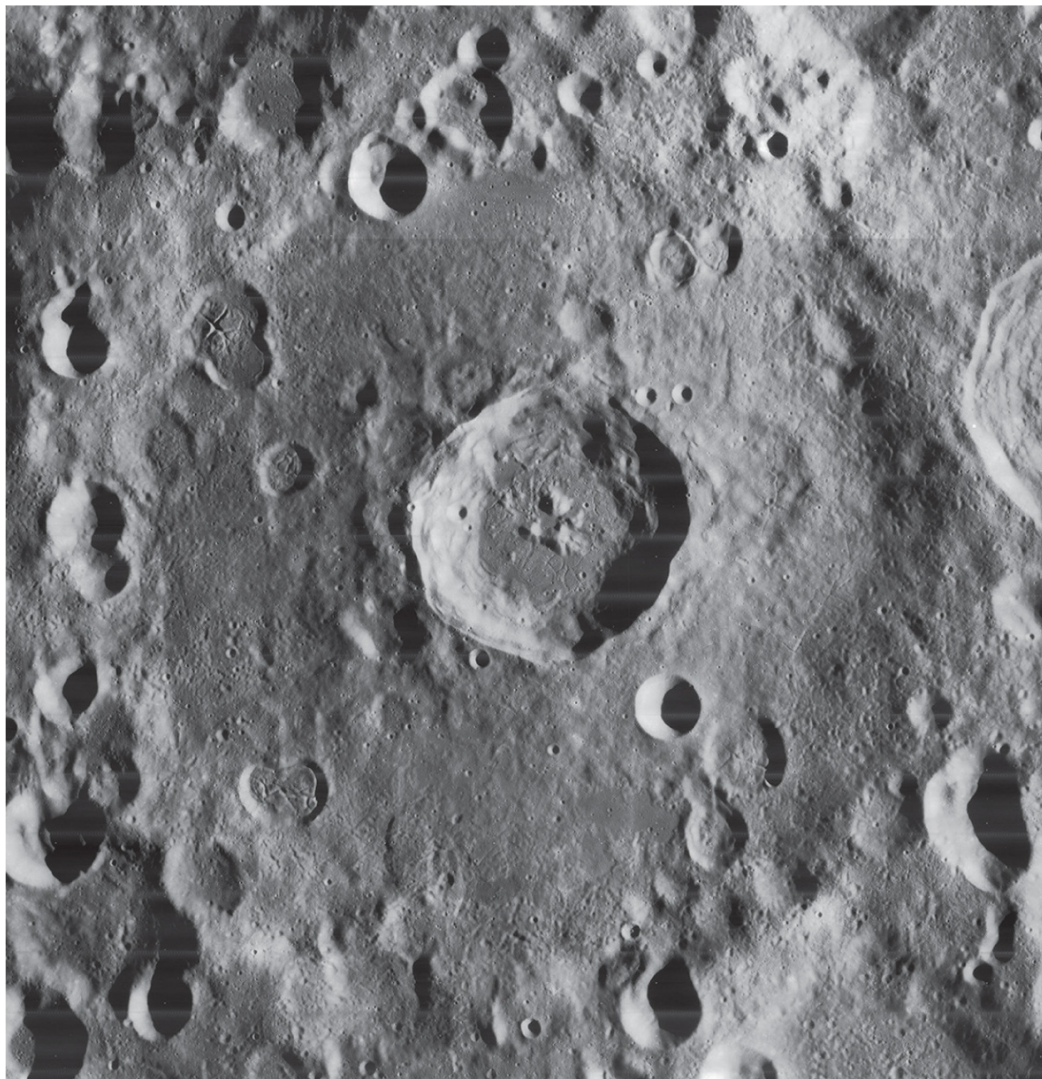


FIGURE 40. The Einstein lunar crater. Although Einstein's scientific work on the Moon was limited to one paper, he is commemorated there by this remarkable feature. The eroded outer ring seen here is quite an old crater. A younger crater is seen at the center, where an impact has made an almost perfect bulls-eye within the older ring. The crater is found on the limb of the Moon, seen only occasionally from Earth when lunar libration makes it possible. (NASA image constructed by James Stuby from two Lunar Orbiter 4 photographs)

Solvay Conferences

The Solvay Conferences were a series of meetings of leading physicists and chemists, arising out of a successful first meeting of specially invited experts held in 1911. Sponsored by a wealthy Belgian industrialist and inventor, Ernest Solvay, the meetings were convened, originally largely at the instigation of Walther Nernst (*see*

Collaborators), to address the important question of how quantum physics could be reconciled with the main body of classical physics.

Einstein was already considered the most insightful thinker on this topic in 1911, though he was one of the youngest scientists in attendance at the meeting. The first meeting addressed the question of radiation and the quanta. As Einstein had shown that the quantum hypothesis could have successes (*see* Concepts, “Photoelectric Effect”) beyond the limited scope of Planck’s original concept (*see* Concepts, “Blackbody Radiation”), it became necessary to debate to what extent light behaved as a particle when it was also known to have the properties of a wave.

Einstein advocated his belief that light had a dual nature, both wave and particle, as early as 1909, and he continued to advocate it in discussions with colleagues at meetings like the Solvay Conferences. But it would take more than another decade before this view became generally accepted (*see* Concepts, “Wave-Particle Duality”).

The second meeting, held in 1913, discussed the nature of matter. This was another area that Einstein had drawn within the sphere of quantum theory (*see* Concepts, “Specific Heat Capacity”), and discussions at this meeting helped to further develop the heat theorem as it became the third law of thermodynamics, through the work of Walther Nernst. Einstein refused his invitation to the third conference in 1921, to protest the exclusion of other German scientists because of national animosities formed during the First World War. (Outside of Germany, Einstein was regarded as an antiwar German who had renounced his German citizenship and retained his Swiss citizenship.)

The important early role the Solvay Conferences played in the development of the quantum theory has been eclipsed by the fame of the Einstein-Bohr debate on quantum mechanics, the public part of which took place at the Solvay Conferences of 1927 (the fifth) and 1930 (the sixth). In these debates, Einstein attempted to show that the theory of quantum mechanics developed by Schrödinger, Heisenberg, and others must lead to contradictions. He advanced a series of thought experiments that Bohr was able, in each case, to reinterpret in a satisfactorily coherent way within the boundaries of the theory. In perhaps the most famous exchange, in 1930, Bohr was able to find the solution to Einstein’s thought experiment overnight, having been stumped by Einstein’s argument the previous day (*see* Thought Experiments, *below*).

As a result of the debates at these conferences, Einstein was obliged to accept that quantum mechanics was a consistent theory as far as it went. He continued to insist, however, that the theory was incomplete and would eventually be superseded by a new theory that is more consistent, in its fundamentals, with classical theories. The conferences continued after 1930 (though with a gap between 1933 and 1948), but without Einstein’s participation. First, the disruption occasioned by the Nazi rise to power and, later, Einstein’s advancing age prevented him from attending.

Thought Experiments

One of the signature characteristics of Einstein’s scientific style was his creative use of thought experiments, or *Gedankenexperimente*, as they are sometimes called. They played an important role in Einstein’s approach to physics. He liked to seize upon a widely confirmed experimental result such as the fact that inertial mass and gravitational mass had always been measured to be exactly equal for every substance tested. He would then elevate this result to the status of a principle (the equivalence principle). Then he could devise experiments that, though impossible to perform in practice, had results that could be predicted on the basis of the equivalence principle.

An example is a thought experiment that likely played a role in the development of general relativity. Responding to naive attempts to replace Newton’s law with a new law modified to conform to special relativity, Einstein pointed out that the new law (proposed by his young colleague Gunnar Nordström; *see* Collaborators) demanded that a body moving at a speed close to the speed of light should fall more slowly than one that was dropped from rest. Einstein pointed out that if Galileo were to perform his famous experiment of dropping two cannonballs from the leaning tower of Pisa, one of them would fall more slowly than the other if it was shot out of a cannon horizontally instead of being merely allowed to fall. No one was in a position to perform this test, since the difference in rate of fall would be insignificant unless the cannonball was fired at nearly the speed of light. Einstein still insisted that

the equivalence principle demanded that they fall at the same rate, and that Nordström's theory, since it thus violated this principle, must be wrong.

A particularly famous thought experiment associated with Einstein is one that he is said to have formulated while still a young man. Suppose you could travel at the speed of light, and could thus keep pace with a light beam. What would you see? You would see the vectors of the electric and magnetic fields that make up the light beam frozen in place. Instead of oscillating back and forth from moment to moment, the fields would travel along with you and thus never change. But, Einstein objected, Maxwell's equations say that a static electromagnetic field can only be supported by nearby charges. It cannot exist off in empty space through which waves can travel. Thus, traveling at the speed of light permits us to observe the theory behaving in an impossible way. It naturally follows that it is impossible to travel at the speed of light, something that later became a central feature of Einstein's special theory of relativity.

Often enough, Einstein would discover a result by calculation and subsequently come up with a particularly compelling demonstration of its truth via a clever thought experiment. A nice example concerns the equation $E = mc^2$ (see Concepts). Although he first proposed this law in 1905, the next year he wrote a new paper that advanced the thought experiment (see Concepts, " $E = mc^2$ "). This thought experiment shows how to move a hollow cylinder by firing light from one end of it to the other. It should be impossible to move the cylinder's center of mass by moving things around inside. The only way to resolve this, Einstein showed, would be to assume that light has mass in proportion to its energy. This concept illustrates the Einsteinian method again. He interprets Newton's third law and the conservation of momentum in order to insist on a general principle that one cannot move one's center of mass without pushing on something outside the system—one cannot pull oneself up by one's bootstraps. Once we concede that point, it follows that if light imparts momentum when absorbed or emitted, it must have mass in direct proportion to its energy.

Some of the best-known stories about Einstein's thought experiments concern his debate with Niels Bohr over the new theory of quantum mechanics. These debates took place primarily at the Solvay Conferences (see above) in the mid- to late 1920s. The most famous thought experiment advanced during these debates was Einstein's box, in which Einstein argued that there must be ways around the then new Heisenberg uncertainty principle. This principle says that one cannot ever have complete information about certain measurable quantities—for instance, one can never precisely measure both the energy of an event and the precise time at which it happened. In the thought experiment, one of these quantities is the energy of a photon emitted at a certain time from a box. Einstein observed that even if the photon cannot have its energy measured with certainty (essentially, because it is so small), one could still weigh the box before and after the emission in order to determine the change in its mass. By the $E = mc^2$ law, one could thus calculate the energy of the photon that was lost from the box system. At first Bohr was dumbfounded by this thought experiment; but after a night's pondering, he realized the solution lay in properly applying the equivalence principle, one of Einstein's most famous ideas. In order to weigh the box, it must sit in a gravitational field on a weighing scale, and we must measure the position at which the box sits on the scale. Thus, we have a problem involving the measurement of position. The equivalence principle demands, however, that the rate of a clock that keeps track of when the photon is emitted must depend on the local strength of the gravitational field, and therefore its rate of running must depend on its precise position in the gravitational field. Thus, any uncertainty in the position of the weighing scale is translated, via the equivalence principle, into an uncertainty in the rate of the clock, and therefore into an uncertainty in the exact time at which the photon was emitted. Thus, as demanded by Heisenberg, any gain in knowledge of the energy of the photon is attained at the price of a loss of precision in measuring the time of emission. In this way, Bohr answered Einstein decisively—a triumph that, in the folk memory of physicists, marked the end of Einstein's challenges to the validity of quantum mechanics.

Unified Field Theory

From the mid-1920s until the end of his life, Einstein's research was focused primarily on the search for a unified field theory (UFT) of gravity and electromagnetism. Such a

theory had been a major preoccupation of late-nineteenth-century physicists whose work had otherwise been completely bypassed and deemed irrelevant by the transformation of field theory wrought by Einstein's special theory of relativity. Between 1910 and 1916, the efforts to develop a theory of gravity compatible with Einstein's reformulation of relativity theory can be seen in some respects as a resumption of this program. This period culminated in Einstein's general theory, leaving other efforts, for instance those of Max Abraham (*see* Rivals) and Gunnar Nordström (*see* Collaborators), again irrelevant—except for the extent to which Einstein himself was able to recast Nordström's effort into the new language of metric theories of gravity that he established.

It did not take other theorists long, once Einstein had provided the framework, to resume the quest to unify gravity with electromagnetism within it. Hermann Weyl, Theodor Kaluza, and Arthur Stanley Eddington, all within a decade of the discovery of general relativity, had shown different ways in which a metric theory might encompass both the field theory of gravity and the field theory of electromagnetism. Interestingly, for these first few years until about 1923, Einstein seems to have shown some resistance to the pursuit of this project. He offered strong objections to Weyl's theory, the first of these three to appear; he showed considerable initial caution in his reception of Kaluza's influential five-dimensional theory; and he seems to have been still somewhat unwilling to devote too much time to the issue when responding to Eddington's work. Yet the very need to investigate these ideas seems to have drawn him into the intellectual excitement of the puzzle, and he became increasingly committed to the unified field quest for the rest of his life. In the 1930s, even his side projects were often strongly motivated by his UFT program, and from 1940 on most of his scientific publications were fairly explicitly connected to his UFT goals, which were essentially threefold:

1. To find a set of field equations from which one could derive the apparently separate field equations of both gravity and electromagnetism.
2. To eliminate the dichotomy of field and particle. Primarily he aimed to show that particles were really epiphenomena of the field, that they were ultimately constructed of pure field. Thus, physics was unitary in the sense that there existed only pure field. The so-called sources of the fields (particles) were themselves complex structures composed of fields.
3. To show that quantum effects ultimately could be explained as the consequence of a classical theory of physics. Thus, he hoped that his unified field theory would be a classical theory that could explain apparently discrete quantum effects.

As time went on, the other problems in physics that interested him became subsumed under these goals. His interest in the quantum theory, which remained strong through his debate with Niels Bohr over the new quantum mechanics in the late 1920s, became bound to his search for a unified theory as he sought ways in which such a theory could produce solutions that mimicked the restrictions of quantum effects. His interest in subatomic physics also played into his UFT efforts, as he sought a theory whose solutions looked like the elementary particles (principally the proton and the electron) known at the time.

The basic approach of the various unification efforts of this period was to take the geometric approach embodied in general relativity and find some "extra" fundamental variables apart from the ten independent variables in the metric tensor (*see* Concepts) that defined the gravitational field. These extra variables could be used to define the electromagnetic field.

From 1919, when he responded rather negatively to Weyl's unified theory, until 1922, Einstein studied the work of others, including Theodor Kaluza's five-dimensional theory and Eddington's affine theory. Around 1923 he began to work earnestly on elaborating his own theory, choosing first to try to further develop Eddington's affine theory. In this early period, he first considered what became something of a signature of his efforts—exploring the possibility that overdetermination of the field equations might yield a theory with quantumlike effects.

Later in the 1920s, he turned toward the five-dimensional approach of Kaluza and then attempted to marry it to the affine program that had been inspired by Eddington. In 1928, he introduced his idea of distant parallelism, in which he

rediscovered the mathematical concept of torsion, previously discovered by Elie Cartan and others (the theory is today known as the Einstein-Cartan theory). He vigorously pursued this promising notion for several years, working with one of his early assistants, Walther Mayer. In the early 1930s, following the interest in Dirac's spinors as a mathematical construct that could describe some of the behavior of fundamental particles, Einstein offered his own rival construct, semivectors. In the mid-thirties, he returned to work on quantum mechanics and general relativity, but in ways that were closely related to his overall goal of seeking clues to the form of a future UFT. In the late 1930s, he returned to the five-dimensional theory. He continued to work closely with his assistants on his unification program from then until the end of his life. He tried introducing a new kind of mathematical construct, which he called a bivector, before settling on an approach that eliminated the requirement from general relativity that the metric of spacetime be symmetric. He worked on this theory with his last, and only, female assistant, Bruria Kaufman, until his death.

Ironically, the unification program in which Einstein participated became irrelevant in its turn as new developments in physics overtook it. Modern unification differs in that (1) it seeks to unify more fields of force (the strong and weak nuclear forces in addition to the two with which Einstein was familiar), (2) it has to explain a far larger group of elementary particles than the ones Einstein considered, and (3) it entirely reverses Einstein's third goal. Modern unifiers hope to find a quantum theory of gravity to replace general relativity, not an elaboration of general relativity that can replace quantum mechanics. The result of this is that most of the ideas that Einstein produced in his UFT papers are no longer relevant to modern physicists. Nevertheless, some of the developments of this period remain relevant today, most notably the five-dimensional theory of Kaluza, which can be seen as a forerunner to string theory, which uses even higher numbers of dimensions. (See also Sauer, "Einstein's Unified Field Theory Program," and van Dongen, *Einstein's Unification*.)

Early Unified Field Theories That Influenced Einstein

Ironically, in view of his later enthusiasm for the project, Einstein was, in the early 1920s, somewhat skeptical of the project of finding a unified field theory (UFT) of physics. Although he followed early efforts in this direction with some interest, he did so in a fairly critical spirit before being drawn into the hunt himself by the mid-1920s. Three theories during this period were particularly influential on Einstein and others.

HERMANN WEYL'S THEORY

Weyl was the first to realize that the details of how we compare vectors between different points of curved spacetime (or how vectors are parallel transported around spacetime) provide a possible set of unknowns that might be used to determine the electromagnetic field, while the metric, which measures distances in space and time, determines the gravitational field. He observed that in Riemannian geometry, a vector transported in parallel fashion to a new location will have the same length as before, but its direction may have changed. Weyl proposed to add a new entity into the theory that could also change the length of the vector as it moved about in space and to associate this new entity with the electromagnetic field. Einstein, while admiring the cleverness of Weyl's mathematical approach, criticized Weyl's theory because it seemed to imply that the behavior of measuring rods and clocks depended on their past history—on where they had been and how they got to where they were.

THEODOR KALUZA'S THEORY

In April 1919, a young mathematician named Theodor Kaluza sent Einstein a paper outlining his idea of introducing a fifth dimension of spacetime into the spacetime geometry underlying Einstein's theory of general relativity. The aim was to provide five extra components of the metric, four of which could be associated with the electromagnetic field. Einstein reacted to this novel proposal with both excitement and skepticism and engaged in a considerable correspondence with the young man. He raised various objections and considered various possible solutions until he had delayed the publication of the paper by some two years.

An example of one of these objections was Einstein's calculation, based on Kaluza's theory, of the electromagnetic and gravitational forces on an electron. The calculation indicated that the latter rather than the former would be by far the stronger for typical fields, which is the opposite of what we observe in nature (for this reason, gravity is often referred to as the weakest force in nature).

In proposing his theory, Kaluza had realized that one way to find extra variables to include electromagnetism in a metrical theory was simply to increase the number of dimensions. A symmetric tensor in four dimensions has ten independent variables ($4+3+2+1$), exactly the number needed to define the gravitational field in Einstein's theory. Adding a fifth dimension immediately yields five new variables, four of which can be used to define the electromagnetic field. This leaves an extra variable in addition to an extra dimension. The mathematician Oskar Klein proposed that the extra dimension might be curled up upon itself so tightly that we cannot perceive it, a proposal that Einstein himself adopted and that is used to this day by string theorists (who generally play with even more than five dimensions). In fact, the theory is generally known today as the Kaluza-Klein theory. The extra variable is often associated with a scalar field, which has only one component, compared to the four of the electromagnetic vector field and the ten of the gravitational tensor field. This modern interpretation was almost prefigured by Einstein in his work on the Kaluza-Klein theory, but he seems to have turned away from considering such a scalar (or dilation) field, most likely because no such field was known in nature.

ARTHUR STANLEY EDDINGTON'S THEORY

Eddington's attempt at unification has some similarities to Weyl's approach, in that it focuses attention on the problem of moving vectors about in spacetime. Eddington drew attention to the role of the affine connection, the technical term for the rule of how to compare vectors that are located in different places. In his theory, this role was to be more fundamental than the metric, which lies at the heart of general relativity. It provided many variables—rather too many—with which to define both the electromagnetic and gravitational fields. Presciently, Eddington wondered if the extra variables might ultimately give some insight into the forces at work within elementary particles, though he had the electron, rather than the proton, in mind. Einstein was more motivated by Eddington's theory than by either of the earlier two. It sparked his initial efforts in the unification program and featured strongly in many of his subsequent efforts over the years.

Part III

Identity and Principles

Civil and Human Rights

Einstein's introduction to the concept of civil rights occurred in 1919, at the very beginning of his political engagement. His first encounter with the concept was a negative one. Convinced that discrimination against Jews in German society, especially against East European Jews, was pervasive, he argued that defending their civil rights in the courts would be of little help to them. Rather, he believed it would only prolong the illusion of assimilation (*see* "Einstein's Confession," *CPAE*, Vol. 7, Doc. 37, published September 24, 1920; and Jewish Identity and Ties, "The Cultural Zionist Ideal," *below*). Separation from the ruling majority alone could offer a guarantee to Germans of Jewish extraction. Ironically, Einstein failed to follow his own advice, as evidenced by the fact that he remained in Germany until late 1932.

As the Nazis stripped Jews and actively dissenting Gentiles of their civil rights in Germany and proceeded to a systematic program of persecution and liquidation, Einstein, now a resident of Princeton, New Jersey, sought to obtain entry into the United States for those increasingly under threat. This consisted for the most part of securing affidavits in support of applications for immigration visas, the large number of which are part of the Einstein Archives. In fact, the sheer number of the affidavits that he signed soon diluted their impact on the authorities. He confessed that he could not "give any more affidavits and would endanger those that are still pending if I were to give more.... The pressure on us from the poor people over there is such that one almost despairs, faced as one is with the depth of misery and the few possibilities of helping" (*see* letter to Michele Besso, October 10, 1938; Einstein Archives 7-376). Horrified by the revelations of the Holocaust and determined to counter measures by the State Department to exclude increasingly desperate refugees, he managed with the help of his influential friend, Rabbi Wise, to convince President Roosevelt to create the War Refugee Board in January 1944. By war's end, 200,000 Jews had been rescued to the United States (*see* [Part I](#), Friends, "Stephen Wise").

Efforts on behalf of the victims of the Nazi terror are most closely linked in the public's mind with the humanitarian Einstein. Yet it was not only in this area that he asserted a spirited defense of the civil rights of the disadvantaged. Of increasing concern to him in the 1930s was the ambitious vision of some in the Zionist camp that threatened both Arab rights and his model of social justice for Palestine. He excoriated the narrow nationalism that called for the disenfranchisement of the Arab population and undermined his aim of coexistence between the two peoples ("The Goal of Jewish-Arab Amity," *New York Times*, April 21, 1935; draft in Einstein Archives 28-305).

During the three winters spent in Pasadena at the beginning of the 1930s, Einstein observed one of the uglier undersides of American society, a rampant racial prejudice against the Negro that denied him basic civil and human rights. He considered prejudice an aspect of the "universal fact that minorities ... are treated by majorities among whom they live as an inferior class." It not only led to disadvantages in economic and social relations; more tragically, "those who meet such treatment themselves for the most part acquiesce in the prejudiced estimate ... and come to regard people like themselves as inferior." Einstein clearly identified the lot of the Negro in America with the Jew in Germany, though a decade later he drew the opposite conclusion. He had seen no future for the Jewish minority in Germany. In America, he hoped that "emancipation of the soul of the minority can be

attained" ("To American Negroes," *The Crisis*, February 1932; Einstein Archives 89-262), though he later admitted that he did "not believe there is a way in which this deeply entrenched evil can be quickly healed" ("The Negro Question," *Pageant*, January 1946; Einstein Archives 28-640).

In Einstein's militant pacifist phase at the beginning of the thirties, he had delivered his famous "Two Percent Speech," advocating civil disobedience in order to paralyze compulsory military service (see *Pacifism*, below). While he soon gave up the idea of Gandhian passive resistance in the face of the Nazis, it was to become the linchpin of his moral stance during the McCarthy period in the early 1950s. He was adamant that those called on to testify about their political views refuse to do so on the grounds that government hearings violated an individual's civil rights (see reference to the open letter to William Frauenglass under Political Contexts, "Postwar and Cold War," and no. 202 in [appendix C](#)). He admonished the socialist Norman Thomas to stop lending his voice to "the hysterical hunt for the few Communists there are here (including those fellow citizens whose red tinge is weaker, à la Jefferson" (see letter to Norman Thomas, March 10, 1954; Einstein Archives 61-549).

Einstein summarized his views on the subject of civil and human rights a month earlier in an address to a lawyer's group: "The existence and validity of human rights are not written in the stars. The ideals concerning the conduct of men toward each other and the desirable structure of the community have been conceived and taught by enlightened individuals in the course of history. Those ideals and convictions which resulted from historical experience, from the craving for beauty and harmony, have been readily accepted in theory by man—and at all times have been trampled upon by the same people under the pressure of their animal instincts. A large part of history is therefore replete with the struggle for those human rights, an eternal struggle in which a final victory can never be won. But to tire in that struggle would mean the ruin of society" ("Human Rights," February 20, 1954; Einstein Archives 28-1012).

Education: Einstein's Views

"The Nightmare"

Einstein's experiences at school and university (see [Part I](#), Education), as student and teacher, were closely related to his views on education. Plagued in his earliest years by the orthodoxy of textbook learning, he stressed the importance of imparting "a vivid sense of the beautiful and of the morally good" through personal contact with teachers. In addition, he thought that "overemphasis on the competitive system and premature specialization ... kill the spirit on which all cultural life depends" (*Ideas and Opinions*, p. 67). He reiterated this forcefully in "The Nightmare" (*Berliner Tageblatt*, December 25, 1917; see *CPAE*, Vol. 6, Doc. 49; Einstein Archives 78-205), in which he rails against the compulsion of the secondary-school leaving examination. This hurdle, he argues, intimidates the pupil, thereby destroying the central purpose of education, which is to foster curiosity and encourage creativity. Here is the full text with original emphases rendered in italics. (Reprinted with permission of The Hebrew University of Jerusalem.)

I consider the secondary-school leaving examination that follows the usual school education *not only unnecessary but even harmful*. I consider it unnecessary because the school faculty is without doubt able to judge the maturity of a young man who attends the school for several years. The teachers' impression of a pupil that is formed during the latter's many years in school and the surely numerous written exercises that every pupil has to complete, together yield a sufficiently complete basis on which to judge a pupil better than any, however carefully implemented examination.

I consider the secondary-school leaving exam harmful for two reasons. *The fear of exams as well as the large number of subjects that have to be committed to memory harm the health of many young men to a considerable degree*. This fact is too well known to need extensive substantive verification. I will nevertheless mention the well-known fact that many men in the most varied professions have been plagued, into their later years, by *nightmares*

whose origins trace back to the secondary-school leaving exam. And these are men who can hold their own in life and can by no means be counted among the neurasthenics.

The secondary-school leaving exam is furthermore harmful because it *lowers the level of teaching in the last school years*. Instead of an exclusively content-oriented engagement with the individual subjects, one all too readily lapses into a more or less *shallow drilling* of the pupils for the exam. Instead of in-depth teaching one gets more or less an *exercise in showmanship* designed to lend the class a certain luster in front of the examiners. *For these reasons, do away with the secondary-school leaving exam!*

“Uproar in the Lecture Hall”

As a member of the Prussian Academy of Sciences, Einstein was not obligated to teach but did offer occasional lecture courses at the University of Berlin. In February 1920, one such lecture on relativity was interrupted by a brouhaha that made the local papers. The uproar began when Einstein announced an open admission policy that violated university regulations. Only registered students, auditors, and docents of the University were entitled to attend. Yet the popularity of Einstein’s lectures knew no bounds after confirmation of general relativity. The overflow crowd of more than 1,500 individuals included a large contingent of unregistered East European Jews. Following the lecture, Einstein opened the floor to a discussion of his newly announced admission standard. For the most part, a decorous exchange ensued, at the end of which an orderly vote was taken in favor of making the lectures open to the public.

In recounting the incident for a liberal newspaper (*8-Uhr Abendblatt*, February 13, 1920; see *CPAE*, Vol. 7, Doc. 33, for the translation used here), Einstein played down the anti-Semitic character of some of the lecture-hall catcalls but conceded that the undertone could be interpreted that way. The student council took the local press to task, viewing the incident as demonstrating the fragility of the academic community when the daily media, irrespective of its political leanings, attempted through distorted press accounts to exploit events within the university. Here is the almost complete text. (Reprinted courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel.)

My popular lectures on the theory of relativity were attended not only by students but also by many individuals who actually were not authorized to attend. For this reason the student council declared that it would no longer tolerate this. I pointed out that the large hall has room enough for all who want to listen and that this should hardly cause any problems. The student council was not satisfied with this and turned this question in to the rector of the university. The rector sent me a letter in which he pointed out that according to existing regulations, these individuals have no right to enter the hall. This is formally correct. I, however, took the point of view that I find it reprehensible to deny these individuals the right to listen without good reason. Therefore, yesterday, instead of lecturing I began a discussion with my audience, which, however, did not lead to a definite result. Consequently, I found it necessary to cancel further lectures and declare to the student body that they could request a refund of their tuition fees. However, I have no intention of canceling my lectures in general; I plan to resume them in a different form.... Should an incident like yesterday’s occur again, I will cease my lecturing altogether.... Anti-Semitic remarks per se did not occur, but the undertone could be interpreted that way.

Jewish Identity and Ties

Allegiances, Old and New

As a young boy in Munich, Einstein received Jewish religious instruction at the home of a distant relative, though this influence was superseded at age twelve by a fascination with the natural sciences. Upon obtaining Swiss citizenship in 1901, for

instance, he declared himself to be “without religious affiliation.” Nor in the almost twenty years that he spent in Switzerland—completing his secondary education, attending and teaching at the university, and working at the Swiss Federal Patent Office—did he have any sense of belonging to a Jewish religious or cultural community. He “was unaware of his Jewishness, nor was there anything present there which affected or stimulated my Jewish sensibility” (“Wie ich Zionist wurde” [How I Became a Zionist], *Jüdische Rundschau*, June 21, 1921; republished in *CPAE*, Vol. 7, Doc. 57).

Religious affiliation received particular attention during Einstein’s three-semester intermezzo at the German University in Prague, 1911–1912. It was the Austro-Hungarian Emperor Franz Joseph’s particular hobbyhorse to demand that all civil servants, including university personnel, profess allegiance to one of the four established religions in the Empire—Roman Catholicism, Lutheranism, Calvinism, or Judaism. Atheism was not tolerated—nor was Islam—and a clash with Einstein’s long-standing declaration of nonaffiliation seemed inevitable. The ever-pragmatic candidate realized, however, that he would be sacrificing his position in Prague if he were to act on conviction. With equanimity, he announced that it mattered not at all “to return to the bosom of Abraham. It is merely a piece of paper that must be signed” (cited in a letter from Paul Ehrenfest to Tatiana Ehrenfest, February 25, 1912, Museum Boerhaave, Leyden).

During his time in Berlin and after, Einstein continued to maintain that he did not believe in anything that might be described as “Jewish faith,” and resisted becoming a member of a Jewish congregation. At the same time, his identification with the disadvantaged Jews from Eastern Europe who suffered most from the burgeoning anti-Semitism in postwar Germany shifted the weight of his concern from the religious aspects of Judaism to cultural ones, and here his conviction was principled and steadfast.

In spite of his own religious indifference, Einstein did not see a contradiction between a Jewish religious outlook and the outlook of science. To his mind, Judaism did not demand an act of faith but was concerned almost exclusively with a moral attitude in life and toward life, of which a scientist could certainly partake. He derived comfort from the stern rationality of Spinoza and looked askance at the concept of a transcendent God. (For more on Einstein’s thoughts on religion and ethics, see the frontmatter, Credo: “What I Believe,” and Religion, *below*.) Baruch Spinoza, a seventeenth-century Jewish philosopher who lived in the Netherlands, broke with the prevailing dogmas of Judaism, arguing that the laws of the Torah were obsolete. For this he was excommunicated from his congregation as a heretic, a fate that the indifferent Einstein was spared.

Catalyst: The Role of Kurt Blumenfeld

Kurt Blumenfeld was the chief ideologue of the German Zionist Federation and the critical catalyst in Einstein’s turn to the Jewish nationalist cause of Zionism in 1919. After engaging in intensive discussions with this persuasive Zionist leader and attending one of his lectures in the beginning of that year, Einstein declared his newfound loyalty with the following metaphor: “I am *against* nationalism, but I am *for* the Zionist cause ... If a man has both arms and constantly asserts ‘I have a right arm,’ then he is a chauvinist. If a man is missing his right arm, however, he must do all in his power to compensate for the missing limb.” This is how Blumenfeld many years later recounted Einstein’s sudden commitment to the Zionist cause. The power of the anecdote lies in its capture of an emotional leap rather than in the precise historical reconstruction of Einstein’s transformation (see Blumenfeld, *Erlebte Judenfrage* [The Jewish Question Experienced], pp. 127–128). In Einstein’s eyes, Zionism’s nationalist coloration was dimmed by the expectation that it might achieve the internationalist goal of bridging with common purpose the fragmented Jewish communities of Europe. Thus he was able to reconcile the tug of Zionist nationalism and his heartfelt belief that intellectuals had a moral obligation to strive for international solidarity.

Blumenfeld also convinced Einstein to accompany the leaders of the World Zionist Organization (WZO) to the United States in 1921 in order to raise money for the Hebrew University of Jerusalem. In doing so, he pointed out to the leadership that Einstein was above all a nonconformist, and while he could always be counted on to support the Zionist cause, caution should be exercised in letting him make speeches in

America, as he might say things that were detrimental to the cause.

Blumenfeld remained a mentor in Zionist matters for the rest of Einstein's life, though the two parted ways over Blumenfeld's more militant and political interpretation of Zionism's goals. (A discussion of Einstein's opposing view of Zionism follows below.) Einstein wrote him in 1944 that he sometimes had the feeling that Blumenfeld was his literary doppelgänger: "This is apparent from the fact that you can copy my style so effortlessly that after a certain time I can no longer tell which one of us was actually the author" (Blumenfeld in Seelig, ed., *Helle Zeit-Dunkle Zeit*, p. 77). Less than a month before his death, Einstein again thanked Blumenfeld for "helping to make me aware of the Jewish soul" (see letter to Blumenfeld, March 25, 1955; Einstein Archives 59-274).

The Cultural Zionist Ideal

By 1920, Einstein was openly contemptuous of the assimilationist position that proposed integrating Jews into German society. In particular, he scorned the policy of maintaining religious practices while rejecting a Jewish cultural identity. The institutional embodiment of this policy was the Central Association of German Citizens of the Jewish Faith, which saw accommodation as a way of guaranteeing Jewish civil rights. Einstein's contempt for the association was to a large degree fueled by his disdain for an elite organization of German Jews that sat in judgment of powerless cousins from the lower classes. By its very name, it denied kinship to its East European brethren. Called upon to address the group in the spring of 1920, Einstein refused, arguing that yielding to the hegemonic German culture was tantamount to seeking approval from the Gentile community. It was, he thought, a fatal concession to the normative authority of the anti-Semite and one that perpetuated humiliation. Only by expressing solidarity with an East European Jewish community that had maintained authenticity through loyalty to its roots, might assimilated German brethren recapture feelings of communal worth (see "Einstein's Confession," in *Israelitisches Wochenblatt für die Schweiz*, September 24, 1920, reprinted in *CPAE*, Vol. 7, Doc. 37). Zionism afforded this promise.

A movement that arose at the end of the nineteenth century, Zionism advanced the proposition that the Jewish people constitute a nation and are entitled to a national homeland. All Zionists agreed that the fatal illusions of assimilation could best be avoided by undertaking tasks in common, and all concurred that Palestine was the heart of such an enterprise. Yet the question remained how best and how realistically that might be achieved.

The Balfour Declaration of 1917 had recognized the Zionist aim of a national home for the Jewish people. In setting up a British mandatory authority three years later, the League of Nations used the same expression: "national home." Much in the development of Zionism over the next thirty years would hinge on the interpretation of this phrase. Two points of departure dominated within the Zionist camp. One stressed Zionism's spiritual and cultural character, the other, its political nature. Cultural Zionists directed their energies toward a Palestine that would rekindle a sense of self-worth in the Diaspora, and in which Palestine and the Diaspora would enjoy a constant reciprocal spiritual relationship. They sought relatively modest funding for gradualist settlement that was committed to the social and economic development of Palestine as a spiritual resource for world Jewry. Political Zionists, on the other hand, wished more or less openly to advance an agenda for the formation of an independent political entity, that is, a state. They dwelled on the importance of mass colonization and ambitious supporting budgets to achieve this goal. Einstein, it is clear, viewed Palestine as a universal symbol of Jewish cultural unity rather than as the seedling of a politically independent nation.

While always placing the greatest emphasis on the cultural aspect of the Zionist enterprise, Einstein did recognize the need for administrative, economic, and social organizations to galvanize it into action. At an early stage of settlement, however, he felt the exercise of power would not endanger the moral purpose that lay at the heart of the enterprise.

This then was Einstein's Zionist ideal: Palestine as a synthesis of tradition and modernity, linking the communal enthusiasm of shtetl Jews with the rational spirit of the secular Enlightenment. The construct could also bridge the differences between cultural and political Zionists, reconcile the fervor of the righteous with the

pragmatism of the pioneer, and give the analytic rigor of the intellectual full play.

Hebrew University of Jerusalem

Though Einstein only took an active interest in Jewish concerns after the First World War, the foundation for his devotion to the Hebrew University was laid in his youth and was rooted in a sense of obligation. According to his sister, very early in his life he felt a responsibility to those fellow-Jews in Europe who were denied “an independent domain” in which to develop their intellectual gifts (see Maja Winteler-Einstein’s memoir, “Beitrag für sein Lebensbild” [Biographical Sketch], February 15, 1924, *CPAE*, Vol. 1, p. lx). The solution was to create an institution of higher learning that would form internationally renowned research departments: “This university will not just form the intellectual center of Jewish Palestine, but will mightily increase the sense of solidarity among the numerous academically employed Jews scattered throughout the world. That a place for free research should already be provided at such an early stage in the development of construction projects in Palestine is consistent with our people’s particular love of the intellectual” (see letter to Sylvio de Mayo, August 22, 1923; Einstein Archives 36-866). For Einstein, the Hebrew University provided the centerpiece of his cultural Zionist aspirations.

In the spring of 1921, Einstein had an opportunity to put this vision into practice. Asked to accompany Chaim Weizmann and other leaders of the World Zionist Organization to the United States on a fund-raising journey on behalf of the Hebrew University, he quickly agreed, “scarcely giving it more than five minutes of thought” (see letter to Fritz Haber, March 9, 1921, *CPAE*, Vol. 12, Doc. 88; Einstein Archives 12-332). The tour was only a qualified financial success, and his later association with the university, the cornerstone of which he laid on his only trip to Palestine in 1923, was not a happy one. Einstein’s dispute with the administration of the Hebrew University was both personal and one of principle. Impatient with the intrigues of its first chancellor, Judah Magnes, he further resented what he thought was the latter’s incompetence compounded by stubbornness. Einstein was above all concerned that the university become an international center of learning and not a provincial backwater. In the face of Magnes’s opposition, Einstein fought to keep academic and administrative control in the hands of recognized European scholars, at the same time belittling the intellectual authority of those in Jerusalem. Multiple threats on his part to resign from the governing bodies of the university, as well as actual resignations and reluctant resumption of oversight duties, haunted his relationship with the university in the late 1920s. The upshot was that an exasperated Einstein became thoroughly alienated from the very institution that had first attracted him to the Zionist fold. (See Rosenkranz, *Einstein before Israel*, chapters 5 and 7, for an excellent discussion of Einstein’s relationship to the university.)

The Jewish Question and Its Resolution

Einstein waded into the political waters that swirled around the Jewish question in 1920 when he brusquely refused to address the Central Association of German Citizens of the Jewish Faith. He also tangled with the World Zionist Organization (WZO) when he publicly took issue with its political Zionist goal of establishing a Jewish state (see “The Cultural Zionist Ideal,” *above*). His differences with that organization became increasingly evident as his prediction that Palestine would be unable to absorb large-scale immigration (see letter to Maurice Solovine, May 20, 1923; Einstein Archives 80-845) proved far off the mark.

Under the relentless persecution and wholesale murder of European Jews, the growing influx of immigrants into the British mandate of Palestine in the 1930s, as well as the uncharitable restrictions on their admission to Western countries, increased the importance of Palestine as a potential place of refuge. Yet, under Arab pressure, Great Britain refused to allow large-scale Jewish immigration. In eventually recognizing the viability of the Jewish presence in Palestine, Einstein began excoriating the British policy of coldheartedly denying European Jews sanctuary and of pitting Jew against Arab. During the Second World War and after, he was tireless in his devotion to the cause of rescuing Jewish refugees from the Holocaust, writing countless affidavits to secure them positions in the United States.

For some time, Einstein had also feared the narrow nationalism of militant Zionists who engaged in land speculation and displayed a brutal indifference to Arab rights in Palestine. Social justice, as Einstein saw it, was the defining characteristic of Judaism, and from this basic assumption he derived political consequences that were often uncomfortable for the Zionist leadership, much as Kurt Blumenfeld had predicted (see “Catalyst: The Role of Kurt Blumenfeld,” *above*). Fearing that the spiritualization of the Jewish community in Palestine would suffer if a Jewish state was created, he bluntly stated his opposition to the idea (“Our Debt to Zionism,” *New Palestine* 28, no. 16 [April 29, 1938]: 2). Einstein’s emphasis on the moral foundations of Zionism as well as his internationalist and pacifist views were increasingly at odds with the mainstream of the Zionist movement.

Einstein’s moderate position on the nature of the Jewish homeland was increasingly being overwhelmed by events. In May 1942, the chairman of the Jewish Agency’s Palestine Executive and later the first prime minister of Israel, David Ben-Gurion, openly called for the creation of a Jewish army and transformation of postwar Palestine into an independent Jewish commonwealth. Einstein continued to resist, calling for a binational solution, but as the full horror of the systematic genocide of European Jews was revealed, the dynamic in favor of a Jewish state became increasingly irresistible. In the end, Einstein accepted its creation but on the condition that it meet the critical test of upholding the ethical ideal of “peace, based on understanding and self-restraint, and not on violence” (“The Jews of Israel,” November 27, 1949, in *Out of My Later Years*, pp. 274–276).

On the question of the political future of Palestine, Einstein’s paramount consideration was the necessity of accommodation between Jew and Arab. He sought reasonable agreement with the Arabs on the basis of living together in peace rather than the creation of a Jewish state, which with borders, an army, and a measure of temporal power undermined any such rapprochement.

He accepted the founding of the state of Israel in 1948, though he never wavered in his conviction that the supreme moral test of a Jewish presence was “our attitude toward our Arab minority ... the true touchstone for our moral standard” (see letter to Zvi Lurie, January 4, 1955; Einstein Archives 60-388).

TESTIMONY BEFORE THE ANGLO-AMERICAN COMMITTEE

Einstein did not try to disguise his contempt for the British policy of divide and conquer that satisfied neither Jew nor Arab. He also caused consternation among many Zionists by reiterating his resistance to the idea of a Jewish state and calling for a binational solution to the Palestine issue. In early January 1946, Einstein appeared before a joint Anglo-American Committee of Inquiry on Jewish Problems in Palestine and Europe to examine the Palestinian issue. The goal of the Committee was to assess political, economic, and social conditions in Mandatory Palestine relevant to the problem of Jewish immigration and settlement. The British government had suggested the inquiry, fearing Arab resistance to the influx of Jewish immigrants into Palestine and hoping to secure American co-responsibility for its Palestinian policy, which was refused. The British then turned to the United Nations. What follows are extracts from Einstein’s testimony before the Committee, which met in the State Department Building, Washington, DC, on January 11, 1946.

Einstein: *I wish to explain why I believe that the difficulties between the Jews and the Arabs are artificially created, and are created by the English. I believe, if there would be a really honest government for the people there, and get the Arabs and the Jews together, there would be nothing to fear. I cannot convince you, gentlemen, but I can only say what convinces me.*

I may first state what I think about British colonial rule. I find that the British colonial rule is based on a native. Do you know what that means? The native was exploited already before the English came into the land. Of course, the English had two interests. The first was to have raw materials for their industry. Also the oil in those countries. I find that everywhere there are big land owners who are exploiters of that race of people. These big land owners, of course, are in a precarious situation because they are always afraid that they will be gotten rid of. The British are always in a passive alliance with those land-possessing owners which suppress the work of the people in the

different trades.

It is my impression that Palestine is a kind of small model of India. There is an attempt to dominate, with the help of a few officials, the people of Palestine, and it seems to me that the English rule in Palestine is absolutely of this kind. It is difficult to imagine how it could be otherwise [...]

Committee member Frank Aydelotte: *What would you do if the Arabs refused to consent to bringing these refugees to Palestine? Suppose the Arab population were prepared to resist it by force; would you compel them by force to receive the refugees?*

Einstein: *That will never be the case if there is not politics. But there are not only Arab politicians, but Jewish politicians, as well.*

Committee member James McDonald: *Would you eliminate the Jewish and Arab politicians both?*

Einstein: *No, you cannot eliminate them. If you eliminate them, ten others grow up in their place. [Laughter.] [...]*

Committee member Joseph Hutcheson: *I have asked various persons if it is essential to the right or the privilege of Jews to go to Palestine, if it is essential to real Zionism, leaving out of the picture the political side of the question, that a setup be fixed so that the Jews may have a Jewish state and a Jewish majority without regard to the Arab view. Do you share that point of view, or do you think the matter can be handled on any other basis?*

Einstein: *Yes, absolutely. The state idea is not according to my heart. I cannot understand why it is needed. It is connected with many difficulties and a narrow-mindedness. I believe it is bad.*

Organizational Ties

Einstein did not join many organizations. For groups whose goals he supported, however, he allowed his name to be used, which gave the false impression that he was also an active member. An independent thinker, he was not one to give his unequivocal allegiance to any political party. Even the Zionists were aware that Einstein was not a man to toe the line.

He did actively participate in the organizations discussed below.

Olympia Academy

The “academy” was a discussion group of three young men, launched Easter 1902 in Bern by Einstein and Maurice Solovine, which Conrad Habicht subsequently joined (fig. 41). Addressing the academy a half-century later, he recalled that it was “established ... in order to make fun of your large, old and self-important sisters” (see letter to the immortal Olympia Academy, April 3, 1953; Einstein Archives 21-294). Einstein was chosen as honorary president and signed “official” letters as “A, Ritter v. Steissbein” (“A[lbert], Knight of the Tailbone”; see letter to Conrad Habicht, December 14, 1909, CPAE, Vol. 5, Doc. 191; Einstein Archives 12-412). The group had its beginnings when Solovine followed up on an advertisement in a Bern newspaper that offered private lessons in physics for three francs an hour (see “Advertisement for Private Lessons,” CPAE, Vol. 1, Doc. 135, which only mentions that the first lesson is free). After meeting a few times, Einstein informed his pupil: “You don’t have to be tutored in physics; our discussion of problems that stem from it is much more interesting. Just come to see me and I will be glad to talk with you.” They began reading Karl Pearson’s *Grammar of Science*, and were soon joined by Habicht, whom Einstein knew from Schaffhausen and who was working on his doctorate in mathematics in Bern. The friends subsequently read and discussed a daunting list of works, including Mach’s *Analysis of Sensations* and *Mechanics*; Mill’s *Logic*, particularly Book III (dealing with induction); Hume’s *A Treatise of Human Nature*; Spinoza’s *Ethics*; some of Helmholtz’s memoirs and lectures; some chapters from Ampère’s *Essay on Philosophy*; Riemann’s *On the Hypotheses Which Serve as a Basis for Geometry*; some chapters from Avenarius’s *Critique of Pure Experience*; Clifford’s *On the Nature of Things in Themselves*; Dedekind’s *What Are Numbers?*; Poincaré’s *Science and Hypothesis*; Sophocles’ *Antigone*; Racine’s *Andromaque*, Dickens’s *Christmas Tales*; most of *Don Quixote*, etc. They reveled in their dinners together,

which were “models of frugality. The menu ordinarily consisted of one bologna sausage, a piece of Gruyère cheese, a fruit, a small container of honey and one or two cups of tea” (*Letters to Solovine, 1906–1955*, pp. 5–15). The group began to dissolve in summer 1903 when Habicht finished his doctoral work in Bern and returned to Schaffhausen before taking a position in eastern Switzerland. Einstein may have continued discussions with Solovine intermittently even after 1904, when he began auditing courses in Lyon, but certainly no longer than 1906, when Solovine moved to Paris.



FIGURE 41. The Olympia Academy members, ca. 1903. Conrad Habicht, Maurice Solovine, and Einstein. (Wikimedia Commons)

Bund Neues Vaterland (Association for a New Fatherland)

Bund Neues Vaterland (BNV) was a pacifist organization, founded in November 1914, shortly after the outbreak of the First World War. It attracted individuals from a political spectrum that stretched from the center to the left and encouraged political and economic understanding among members of the European cultural community. Most attractive for Einstein was its effort to reestablish the international “republic of letters” and restore the bonds of cooperation among intellectuals from the belligerent states.

Einstein first attended a meeting of the organization as a guest, together with his cousin, Elsa Löwenthal, in March 1915. At this time, Einstein was still struggling with his general theory of relativity and most probably accompanied Elsa as a favor to her. His political mentor, Georg Nicolai (see [Part I](#), Friends), presumably also urged Einstein’s attendance. By the beginning of June, he had become a member. In the course of its first year, the organization’s ringing condemnations of the policy of German annexation and its intimate connections with the Dutch Anti-War Council resulted in disbandment by the authorities in February 1916.

As the war was ending, September 1918, the association was reconstituted. As a member of a working committee, Einstein called for the construction of a German socialist republic on a democratic foundation that was committed to the task of international reconciliation. With others, he also delivered a speech under BNV auspices in November 1918 that insisted on the immediate convening of a National Assembly with legislative powers and warned of a dictatorship of the proletariat (see “Need for a National Assembly,” November 13, 1918, *CPAE*, Vol. 7, Doc. 14; Einstein Archives 28-001). More than a thousand people attended. In addition, the reconstituted organization pursued the question of war guilt and how to facilitate the introduction of civil liberties while seeking a middle ground between the extremes of

the revolutionary left at home and foreign demands for vengeance.

A year later, in his capacity as a BNV spokesman, Einstein welcomed a board member of the French Clarté movement who spoke in the former Prussian House of Lords about setting up a “brain trust” to facilitate international reconciliation. Einstein even briefly entertained the suggestion that he head a German branch of Clarté. On a trip to Amsterdam under BNV auspices in February 1921, after a liberal constitution for the Weimar Republic had been adopted (August 1919), Einstein urged the International Federation of Trade Unions to intervene on Germany’s behalf in Allied debates about the republic’s crushing burden of reparations.

Einstein’s swan song as an active participant in public activities of the BNV—now renamed the German League for the Rights of Man—came at a joint peace meeting of German and French delegates in Berlin in June 1922. Returning to a theme he had touched on many times before, in his speech he called for a bridge over the abyss that separated different cultures by subordinating the needs of one’s own country to the interests of a greater European union (*see* “Address to the French-German Peace Meeting,” June 11, 1922, *CPAE*, Vol. 13, Doc. 228). In early 1926, Einstein asked to resign from the executive committee of the German League, citing other pressing obligations (*see* letter to Otto Lehmann-Russbueldt, January 3, 1926; Einstein Archives 44-328).

International Committee on Intellectual Cooperation

Apart from his ties with the Bund Neues Vaterland, Einstein confined his organized political activity during the early and mid-1920s mainly to working with the International Committee on Intellectual Cooperation (ICIC) affiliated with the League of Nations. His on-again-off-again relationship with this elite body reflected not only the volatile state of European politics but the varying level of his disappointment with the spinelessness of the League. Stubbornly his own man, Einstein also inclined to the view that he was acting in his capacity as an individual, not as the spokesperson of national policy. Though he favored the idea that intellectual elites should have a platform for voicing their views on human affairs, he came to feel that the ICIC could not live up to this goal because the constraints of national interest hampered its efforts.

The assassination of Einstein’s friend, the German-Jewish foreign minister Walther Rathenau, in June 1922, as well as rumors that he too had been placed on death lists, led to his first announcement of resignation from the committee that he had joined less than a month earlier. When fellow member Marie Curie urged him to stay on, he reconsidered. A second resignation followed in spring 1923 after his return from the Far East. This time it was the impotence of the League of Nations in the face of the French-Belgian occupation of the German industrial heartland of the Ruhr that prompted his withdrawal (*see* letter to Pierre Comert, April 11, 1923, *CPAE*, Vol. 14, Doc. 10; Einstein Archives 34-799). The formation of a more conciliatory French government a year later brought another change of heart. Einstein expressed regret for his “temporary demoralization” and asked to rejoin the ICIC (*see* letter to Gilbert Murray, May 30, 1924, *CPAE*, Vol. 14, Doc. 258; Einstein Archives 34-808).

After attending the fourth session of the group in late July 1924, Einstein explained the goal of the commission in a prominent German newspaper: “We are not so much concerned with utopian plans, but have already begun with more modest, but fruitful detail work: the international organization of reporting scientific research, exchange of publications, protection of intellectual property, exchange of professors and students of various countries, etc. The greatest emphasis has been placed on the problem of reporting scientific work.” Of greater interest to the general public, he admitted, was the question of Germany’s entry into the League of Nations, of which he was a strong proponent (*see* “On the League of Nations,” August 29, 1924, *CPAE*, Vol. 14, Doc. 314).

His initial misgivings that the group lacked the determination necessary to achieve real progress toward improving international relations only grew when the committee’s work was taken over in 1926 by the Paris-based Institute for Intellectual Cooperation. Einstein regarded the institute’s exclusive funding by the French government as a naked intrusion of national interests in the committee’s work and an unacceptable undermining of its internationalist mission. Disheartened by unsuccessful efforts to interest Max Planck in setting up a German national

commission of moderates as a counterweight to French influence, Einstein tendered his final resignation from the ICIC in 1932.

Emergency Committee of Atomic Scientists

Well before the August 1945 bombings of Hiroshima and Nagasaki that ended the Second World War, Einstein had developed grave concerns about containing that which he had helped set in motion (*see* letter of March 25, 1945, in Politics, “Hitler in Power and the Second World War—Letters to FDR,” *below*). Someone else who shared these misgivings was Leo Szilard, who in summer 1939 had prevailed upon Einstein to put his name on a first letter to President Roosevelt that only two years later indirectly precipitated the Manhattan Project. By accepting the chairmanship of Szilard’s brainchild, the newly created Emergency Committee of Atomic Scientists (ECAS) in May 1946, Einstein did so with the intent of lessening mistrust and increasing accord between the United States and the Soviet Union, the two premier powers to emerge from the war. Einstein and Szilard recognized that an American monopoly on atomic power was an illusion and that the United States would soon be joined in the atomic club by the Soviet Union. (In late August 1949, the Soviets conducted their first atomic weapons test and followed this up with a thermonuclear device—a hydrogen bomb—four years later).

The ECAS, initially comprised of eight distinguished physicists and chemists as trustees, had no pretensions to make policy. Its primary aim was to improve communications between atomic scientists and the public. To that end it released a “Statement of Purpose” that included the following facts on which, so it claimed, all scientists had achieved a consensus. Atomic bombs could be made cheaply and in large numbers, and their destructive capabilities would rapidly increase; there was no military defense against atomic weapons and none was to be expected; other countries would soon be able to replicate processes leading to atomic weaponry; no state of preparedness against atomic war was possible and if attempted, would destroy the social fabric; civilization would be destroyed in any conflict in which atomic bombs were deployed; so that the only solution lay in international control of atomic energy, and ultimately in the elimination of war.

The following excerpts from an interview given by Einstein one month after the inception of the ECAS was originally published in the Sunday magazine section of the *New York Times*, and reprinted by the ECAS for distribution in its fund-raising activities:

Often in evolutionary processes a species must adapt to new conditions in order to survive. Today the atomic bomb has altered profoundly the nature of the world as we knew it, and the human race consequently finds itself in a new habitat to which it must adapt its thinking.... Our defense is not in armaments, nor in science, nor in going underground. Our defense is in law and order. Henceforth, every nation’s foreign policy must be judged at every point by one consideration: Does it lead us to a world of law and order or does it lead us back toward anarchy and death? I do not believe that we can prepare for war and at the same time prepare for a world community. When humanity holds in its hand the weapon with which it can commit suicide, I believe that to put more power into the gun is to increase the probability of disaster.... Science has brought forth this danger [of atomic war], but the real problem is in the minds and hearts of men. We will not change the hearts of other men by mechanisms, but by changing *our* hearts and speaking bravely” (“The Real Problem Is in the Hearts of Men,” *New York Times Magazine*, June 23, 1946; republished in Nathan and Norden, *Einstein on Peace*, pp. 383–388).

According to one of its members, Nobel Prize winner Linus Pauling, the committee was officially disbanded in 1951, nearly five years after its formation, largely because of the strain that committee work placed on an aging Einstein. While it may have been a contributing factor, the demise of the organization was at heart more political and financial. Donations in support of nuclear nonproliferation activism began to diminish. Even more significantly, the rift between the United States and the Soviet Union continued to grow as the consensus within the ECAS broke down. Many

committee members held opposing views concerning the U.S. government's intention to develop and produce the hydrogen bomb. Similarly, there were sharp disagreements about how to organize and implement a world government that all agreed was necessary to prevent atomic war. The final meeting of the Board of Trustees was held on September 8, 1951.

Political Contexts

The First World War and the Weimar Republic, 1914–1932

A resurgent interest in Judaism and a tentative articulation of internationalist sentiments mark the first phase of Einstein's involvement in politics. The move from Switzerland to Berlin in spring 1914 and the outbreak of the First World War jolted sensibilities that for years had lain dormant while he devoted himself single-mindedly to the pursuit of physics. Once in the German capital, his outrage at the harassment of Jewish immigrants from Eastern Europe led to his first political article on their behalf for a mass-circulation newspaper. Fearing that the war would do irreparable harm to the international character of science, he signed a public appeal immediately after hostilities began, protesting the German Army's violation of Belgian neutrality (see "Manifesto to the Europeans," *below*). His participation in a short-lived pacifist organization gave him access to a network of politically like-minded individuals outside the world of science (see *Organizational Ties*, "Bund Neues Vaterland," *above*). In 1916, he published an essay in which he agreed with Tolstoy's comparison of patriotism to a mental disorder ("My Opinion on the War," *CPAE*, Vol. 6, Doc. 20; Einstein Archives 70-457. See also no. 59 in [appendix C](#)).

Though many imperial institutions and elites survived unscathed into the successor Weimar Republic, Einstein recognized that his views on moral and political issues, confined to private letters and the occasional publication during the war, would be broadcast throughout the world and carry great weight, especially now that he was world-famous. It is under these circumstances that he found his public voice and deepened his political commitment.

In the postwar period, he participated in various initiatives to obtain funding for research in the defeated countries, chiefly in his capacity as a member of the Emergency Society for German Science and Scholarship. His condemnation—in correspondence and publications—of the harsh terms of the Versailles Peace Treaty and the opinion that the Allies might be the lesser of two evils reveal his evolving independence of judgment. Less than a year after the cessation of hostilities, he stated what would become a lifelong leitmotif: "I don't believe that humanity as such can change in essence, but I do believe that it is possible and even *necessary* to put an end to anarchy in international relations, even though the sacrifice of autonomy will be significant for individual states" (see letter to Hedwig Born, August 31, 1919, *CPAE*, Vol. 9, Doc. 97; Einstein Archives 8-254).

Initially, Einstein had high hopes for the supranational League of Nations, but these were frustrated by America's refusal to join and by the League's repeated reliance on economic sanctions as a last resort. Appointed in 1922 to its International Committee on Intellectual Cooperation (see *Organizational Ties*), he attempted for a decade, in an on-again off-again relationship, to counter the intrusion of national interests.

The assassination in June 1922 of the German foreign minister, Walther Rathenau, a Jew and friend of Einstein's, whom he had advised beforehand to give up his exposed position, crystallized Einstein's decision to step back from his own political involvement. The political atmosphere in Germany had degenerated to the point, as Einstein put it, "that a Jew would do well to exercise restraint as regards his participation in political affairs" (Nathan and Norden, *Einstein on Peace*, p. 59). He remained on the political sidelines until 1924.

Although he wrote very little on European politics after returning from a lengthy tour of the Far East (1922–1923), he was heartened by the stabilization of the German economy in 1924 that ushered in a brief era of tranquility under the leadership of the German foreign minister, Gustav Stresemann.

Politics was, he thought, too important to be left to politicians: "I believe that there is a political idea and a political task, which no one who claims to be a

contemporary should shirk. By that I mean the task of restoring *the unity between nations* which has been so completely destroyed by the world war ... I am convinced that participating in this is a duty which no one can avoid, however great his achievement in any field whatsoever" (interview given to *Neue Zürcher Zeitung*, November 1927).

The Nazi seizure of power in January 1933 shattered any remaining illusions about Germany. In residence at Caltech in Pasadena at the time, Einstein was determined never to return to his homeland.

MANIFESTO TO THE EUROPEANS

In the first months of the First World War, ninety-three of Einstein's most prominent German colleagues in the arts and sciences signed a "Manifesto to the Civilized World" that expressed solidarity with the German Army's violation of Belgian neutrality. Einstein was outraged by this appeal to narrow nationalism, all the more because it was proclaimed from the ranks of a cultural elite, to which he had recently been recruited. In response, he helped draw up a countermanifesto reaching out to all Europeans. Composed in its first draft by Einstein's friend and colleague, Georg Nicolai, the final version of the document was "collectively decided" upon by Einstein, Nicolai, and two others in mid-October 1914 (*Nicolai 1917*, p. 12). The countermanifesto, officially titled "Manifesto to the Europeans," was circulated among a large number of academics, but aside from its authors, only one graduate student was prepared to sign. Wartime censorship in Germany consigned it to three-year oblivion, from which it only emerged in 1917. In that year, the countermanifesto was published in neutral Switzerland in the preface to a book by Nicolai, *The Biology of War*. Here is Nicolai's translated text, taken from Rowe and Schulmann, *Einstein on Politics*, pp. 64–66:

While technology and commerce clearly compel us to recognize the bond between all nations, and thus a common world culture, no war has ever so intensively disrupted cultural cooperation as the present one. Perhaps our acute awareness of the disruption that we now sense so painfully is due to the numerous common bonds we once shared.

Even should this state of affairs not surprise us, those for whom a common world culture is the least bit precious should redouble their efforts to uphold these principles. Those, however, of whom one should expect such conviction—in particular scientists and artists—have thus far only uttered things which suggest that their desire for maintaining relations has vanished simultaneously with their disruption. They have spoken with an understandable hostility—but least of all of peace.

Such a mood cannot be excused by any national passion; it is unworthy of what the entire world has until now come to understand by the name of culture. It would be a disaster should this mood pervade the educated classes.

Not only would it be a disaster for civilization, but—and we are firmly convinced of this—a disaster for the national survival of individual states—in the final analysis, the very cause in the name of which all this barbarity has been unleashed.

Through technology the world has become *smaller*; the *states* of the large peninsula of Europe today move in the orbit of one another much as did the *cities* of each small Mediterranean peninsula in ancient times. Through a complex of interrelationships, Europe—one could almost say the world—now displays a unity based on the needs and experience of every individual.

Thus it would appear to be the duty of educated and well-meaning Europeans at the very least to attempt to prevent Europe—as a result of an imperfect organization of the whole—from suffering the same tragic fate which befell ancient Greece. Should Europe, too, gradually exhaust itself and collapse in fratricidal war?

The struggle raging today will likely produce no victor; it will probably leave only the vanquished behind. Therefore, it seems not only *good*, but rather bitterly *necessary*, that *intellectuals of all nations* marshal their influence such that—whatever the still uncertain end of the war may be—the *terms of*

peace shall not become the cause of future wars. The fact that through this war European relationships have to some extent become *volatile and malleable* should rather be used to make of Europe an organic entity. The technological and intellectual prerequisites are given.

How this European order is to be brought about should not be discussed here. We wish merely to emphasize as a matter of principle that we are firmly convinced that the time has come when *Europe must act as one in order to protect her soil, her inhabitants, and her culture.*

We believe that the will to do this is latently present in many. In expressing this will collectively we hope that it gathers force.

To this end, it seems for the time being necessary that all those who hold European civilization dear, in other words, those who in Goethe's prescient words can be called "*good Europeans*," join together. After all, we must not give up the hope that their collective voice—even in the din of arms—will not trail off entirely unheard, especially, if among these "*good Europeans of tomorrow*," we find all those who enjoy esteem and authority among their educated peers.

First it is necessary, however, that Europeans get together, and if—as we hope—enough *Europeans in Europe* can be found, that it is to say, people for whom Europe is not merely a geographical concept, but rather a worthy object of affection, then we shall try to call together a union of Europeans. Such a union shall then speak and decide.

We wish only to urge and appeal; and if you feel as we do, if you are similarly determined to *lend the most far-reaching resonance to the European will*, then we ask that you sign.

A LETTER TO SIGMUND FREUD FROM "WHY WAR?"

Einstein's last action as an associate of the League of Nations took place in 1932 after he had already submitted his resignation. Asked to initiate a written exchange of views with another leading intellectual about any major problem facing humanity, he invited Sigmund Freud to discuss the psychological factors at play when nations go to war against one another. Einstein's essay emphasized the deep-seated irrational impulses, normally latent, that well up in wartime. It was a bitter echo of his "*My Opinion on the War*," which he had written during the First World War (*see no. 59 in [appendix C](#)*). (Reprinted courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel.)

Caputh near Potsdam, July 30, 1932

Dear Professor Freud,

The proposal of the League of Nations and its International Institute of Intellectual Co-operation at Paris that I should invite a person, to be chosen by myself, to a frank exchange of views on any problem that I might select affords me a very welcome opportunity of conferring with you upon a question which, as things now are, seems the most insistent of all the problems civilisation has to face. This is the problem: Is there any way of delivering mankind from the menace of war? It is common knowledge that, with the advance of modern science, this issue has come to mean a matter of life and death for civilisation as we know it; nevertheless, for all the zeal displayed, every attempt at its solution has ended in a lamentable breakdown.

I believe, moreover, that those whose duty it is to tackle the problem professionally and practically are growing only too aware of their impotence to deal with it, and have now a very lively desire to learn the views of men who, absorbed in the pursuit of science, can see world-problems in the perspective distance lends. As for me, the normal objective of my thought affords no insight into the dark places of human will and feeling. Thus, in the enquiry now proposed, I can do little more than to seek to clarify the question at issue and, clearing the ground of the more obvious solutions, enable you to bring the light of your far-reaching knowledge of man's instinctive life to bear upon the problem. There are certain psychological

obstacles whose existence a layman in the mental sciences may dimly surmise, but whose interrelations and vagaries he is incompetent to fathom; you, I am convinced, will be able to suggest educative methods, lying more or less outside the scope of politics, which will eliminate these obstacles.

As one immune from nationalist bias, I personally see a simple way of dealing with the superficial (that is, administrative) aspect of the problem: the setting up, by international consent, of a legislative and judicial body to settle every conflict arising between nations. Each nation would undertake to abide by the orders issued by this legislative body, to invoke its decision in every dispute, to accept its judgments unreservedly and to carry out every measure the tribunal deems necessary for the execution of its decrees. But here, at the outset, I come up against a difficulty; a tribunal is a human institution which, in proportion as the power at its disposal is inadequate to enforce its verdicts, is all the more prone to suffer these to be deflected by extrajudicial pressure. This is a fact with which we have to reckon: law and might inevitably go hand in hand, and juridical decisions approach more nearly the ideal justice demanded by the community (in whose name and interests these verdicts are pronounced) insofar as the community has effective power to compel respect of its juridical ideal. At present, however, we are far from possessing any supranational organisation competent to render verdicts of incontestable authority and enforce absolute submission to the execution of its verdicts. Thus I am led to my first axiom: the quest of international security involves the unconditional surrender by every nation, in a certain measure, of its liberty of action, its sovereignty that is to say, and it is clear beyond all doubt that no other road can lead to such security.

The ill-success, despite their obvious sincerity, of all the efforts made during the last decade to reach this goal leaves us no room to doubt that strong psychological factors are at work, which paralyse these efforts. Some of these factors are not far to seek. The craving for power which characterises the governing class in every nation is hostile to any limitation of the national sovereignty. This political power-hunger is wont to batten on the activities of another group, whose aspirations are on purely mercenary, economic lines. I have specially in mind that small but determined group, active in every nation, composed of individuals who, indifferent to social considerations and restraints, regard warfare, the manufacture and sale of arms, simply as an occasion to advance their personal interests and enlarge their personal authority.

But recognition of this obvious fact is merely the first step towards an appreciation of the actual state of affairs. Another question follows hard upon it: How is it possible for this small clique to bend the will of the majority, who stand to lose and suffer by a state of war, to the service of their ambitions. (In speaking of the majority, I do not exclude soldiers of every rank who have chosen war as their profession, in the belief that they are serving to defend the highest interests of their race, and that attack is often the best method of defence.) An obvious answer to this question would seem to be that the minority, the ruling class at present, has the schools and press, usually the Church as well, under its thumb. This enables it to organise and sway the emotions of the masses, and makes its tool of them.

Yet even this answer does not provide a complete solution. Another question arises from it: How is it these devices succeed so well in rousing men to such wild enthusiasm, even to sacrifice their lives? Only one answer is possible. Because man has within him a lust for hatred and destruction. In normal times this passion exists in a latent state, it emerges only in unusual circumstances; but it is a comparatively easy task to call it into play and raise it to the power of a collective psychosis. Here lies, perhaps, the crux of all the complex of factors we are considering, an enigma that only the expert in the lore of human instincts can resolve.

And so we come to our last question. Is it possible to control man's mental evolution so as to make him proof against the psychoses of hate and destructiveness? Here I am thinking by no means only of the so-called uncultured masses. Experience proves that it is rather the so-called "Intelligentzia" that is most apt to yield to these disastrous collective

suggestions, since the intellectual has no direct contact with life in the raw but encounters it in its easiest, synthetic form—upon the printed page.

To conclude: I have so far been speaking only of wars between nations; what are known as international conflicts. But I am well aware that the aggressive instinct operates under other forms and in other circumstances. (I am thinking of civil wars, for instance, due in earlier days to religious zeal, but nowadays to social factors; or, again, the persecution of racial minorities.) But my insistence on what is the most typical, most cruel and extravagant form of conflict between man and man was deliberate, for here we have the best occasion of discovering ways and means to render all armed conflicts impossible.

I know that in your writings we may find answers, explicit or implied, to all the issues of this urgent and absorbing problem. But it would be of the greatest service to us all were you to present the problem of world peace in the light of your most recent discoveries, for such a presentation well might blaze the trail for new and fruitful modes of action.

Yours very sincerely, A. Einstein

Source: Einstein and Freud, *Why War?*

Hitler in Power and the Second World War, 1933–1945

A heightened concern for the fate of his fellow Jews and reluctant abandonment of pacifism marked Einstein's political commitment in the twelve-year period beginning with Hitler's seizure of power and the defeat of the Axis in 1945. As wholesale killing of European Jews followed their repression in Germany, Einstein dedicated himself to aid Jewish emigration and resettlement. After the defeat of the Axis powers, his internationalist sympathies were channeled into a tireless pursuit of a world at peace and free of nuclear weapons.

In reaction to the Nazi seizure of power in 1933, he severed ties with Germany and issued statements that characterized his views on political tolerance and condemned the acts of brutality perpetrated by the Nazi government. In one proclamation entitled "Political Manifesto," he compared the disease that had crept into the German social organism with a distemper that affects animals and that had eliminated "political liberty, tolerance, and equality of all citizens before the law" (Political Manifesto, March 11, 1933; Einstein Archives 28-235.1). Similar statements brought heated denials from the German press and led to his loss of German citizenship the following year (see [Part I](#), Citizenships and Immigration to the United States).

Another victim of Hitler's savagery was Einstein's erstwhile militant pacifism. In the face of the German dictator's increasingly hostile behavior, Einstein rejected passive resistance on the individual level and strove for rapprochement among the powers arrayed against Germany. "I do not believe that under present circumstances passive resistance is an effective method, even if carried out in the most heroic manner. Other times, other means, even if the final aim remains the same. The confirmed pacifist must therefore at present seek a plan of action different from that of former, more peaceful times. He must try to work for this aim: That those States which favor peaceful progress may come as close together as possible in order to diminish the likelihood that the warlike programs of political adventurers ... will be realized" ("A Re-Examination of Pacifism," *Polity*, January 1935; reprinted in Nathan and Norden, *Einstein on Peace*, pp. 254–256).

With Europe entering a new era of crisis, Einstein formulated three principles that served as touchstones for his mature political views. He firmly rejected autocratic forms of government while affirming his belief in democracy, despite the recent travails of the Weimar Republic; he upheld the creative individual and not the political state as society's most precious asset; and he characterized the military mentality as the single worst manifestation of the "herd mind" in modern society (see the frontmatter, Credo: "What I Believe").

By the autumn of 1933, Einstein had settled in Princeton, where he soon assumed a completely new role, that of a Cassandra. He put the Allies on notice that "the Germans are secretly rearming on a large scale. Factories are running day and night

(airplanes, light bombs, tanks, and heavy ordnance, produced in part on Swedish territory). A million troops are being covertly trained.” The warning was contained in a private letter but Einstein urged that there be a “quiet *organized* effort directed toward American authorities and the American press” (see letter to Stephen S. Wise, June 6, 1933; Einstein Archives 35-133).

When in 1938, Clifton Fadiman, book editor of the *New Yorker*, asked Einstein to prepare a sequel to his essay “What I Believe,” written eight years earlier (see Credo in the frontmatter), reflecting on what had changed in the world in the ensuing years, Einstein painted a dismal picture: “In these ten years confidence in the stability, yes, even the very basis for existence, of human society has largely vanished. One senses not only a threat to man’s cultural heritage, but also that a lower value is placed upon all that one would like to see defended at all costs” (“Ten Fateful Years,” in Fadiman, ed., *I Believe*, pp. 367–369; reprinted in Einstein’s *Out of My Later Years*, pp. 6–8).

The impact of the Holocaust that was unleashed in Europe in the early 1940s was decisive for Einstein. He never again budged from his conviction of the German people’s collective complicity in the crimes of their government. The near-annihilation of the Jewish people also convinced him that Palestine would have a central role to play in the life of the survivors, though he held to his conviction that a nation-state was not desirable (see Jewish Identity and Ties, “Testimony before the Anglo-American Committee”). The victory of the Allies and the founding of the United Nations gave him renewed hope that a lasting peace might finally be achieved by the integration of conflicting nations into a higher sovereignty or world government.

LETTERS TO PRESIDENT FRANKLIN D. ROOSEVELT ON THE ATOM BOMB

Shortly before the outbreak of the Second World War, Einstein learned from the émigré physicist Leo Szilard that German scientists might use the recently discovered process of nuclear fission to develop a powerful new type of bomb. In late July 1939, at the urging of Szilard and a fellow Hungarian émigré, Eugene Wigner, Einstein helped prepare a letter warning President Roosevelt of this threat. Because of the letter and because the equivalence of mass and energy expressed in his signature formula $E = mc^2$ underlies the relation between nuclear fission and the release of prodigious amounts of energy, Einstein has sometimes erroneously been called “the father of the atomic bomb” (see [Part I](#), Myths and Misconceptions, “Responsible for the Atom Bomb”).

As Einstein explained to the Japanese pacifist Seiei Shinohara after the war, the attribution of such paternity was misplaced. His letter to Roosevelt was only one of many factors that led to the establishment of the Manhattan Project, the enterprise dedicated to the manufacture of nuclear weapons, headed by General Leslie Groves and under the technical direction of J. Robert Oppenheimer. In fact, Einstein’s warning had very little impact. The initial Advisory Committee on Uranium, set up two months after the letter was written, with Leo Szilard, Edward Teller (representing Enrico Fermi), and Eugene Wigner serving as experts on nuclear fission, was superseded in June 1940 by the National Defense Research Committee. Its chairperson, Vannevar Bush, took a wait-and-see approach to nuclear research. It was only when Bush and others read the British government’s MAUD Committee Report in October 1941 on the practicability of a “uranium bomb” that the tide turned. This committee (Military Application of Uranium Detonation) had spearheaded the British atomic bomb project and prompted the United States to begin its own project in the New Mexico desert at Los Alamos. On December 6, 1941, on the eve of Pearl Harbor, the Manhattan Project was finally approved, more than two years after Einstein signed the letter to FDR (which was in fact composed by Leo Szilard, in consultation with Eugene Wigner, and presented to Einstein for his signature). Once under way, moreover, the Manhattan Project, in which British scientists collaborated as well, had no use for Einstein. Labeled a security risk in a confidential report issued by the U.S. Army, he remained officially in the dark about nuclear research throughout the war. In any case, he would have had little to contribute, as he had not kept up with the rapid development of nuclear physics in the 1930s. He did, however, give advice on explosives for the U.S. Department of the Navy.

Texts of two of Einstein’s four letters to FDR follow. The first was hand delivered by economist Alexander Sachs, a confidant of the president, but not until October 11,

after a number of delays. (See all letters in FDR Library at <http://fdrlibrary.marist.edu/>; first letter is in Einstein Archives 39-468.) (Both of the following letters are reprinted courtesy of The Albert Einstein Archives, The Hebrew University of Jerusalem, Israel.)

Peconic, Long Island, August 2nd, 1939

Sir:

Some recent work by E[nrico] Fermi and L[eo] Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable—through the work of [Frédéric] Joliot[-Curie] in France as well as Fermi and Szilard in America—that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is [the] Belgian Congo. In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an unofficial [sic] capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the cooperation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son [Carl Friedrich] of the German Under-Secretary of State, [Ernst] von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly, *Albert Einstein*

Roosevelt replied, in part, on October 19, 1939, as follows: “I have found this letter of such import that I have convened a Board consisting of the head of the Bureau of Standards and chosen representatives of the Army and Navy to thoroughly investigate the possibilities of your suggestion regarding the element of uranium” (Einstein Archives 33-088).

Einstein indirectly wrote two more letters to FDR. One was written on March 7, 1940 (Einstein Archives 39-475), to Alexander Sachs, to be transmitted to FDR, and a second was sent to Lyman Briggs, the head of the secret "Uranium Committee" and director of the Bureau of Standards, on April 25, 1940 (Einstein Archives 39-484), also intended for FDR. Both letters recommended more work on nuclear research. He sent a lesser-known letter (also drafted by Szilard) directly to Roosevelt five and a half years later, on March 25, 1945, as he began to fear the possible misuse of uranium (Einstein Archives 33-109).

Sir:

I am writing you to introduce Dr. L[eo] Szilard, who proposes to submit to you certain considerations and recommendations. Unusual circumstances which I shall describe further below induce me to take this action in spite of the fact that I do not know the substance of the considerations and recommendations which Dr. Szilard proposes to submit to you.

In the summer of 1939 Dr. Szilard put before me his views concerning the potential importance of uranium for national defense. He was greatly disturbed by the potentialities involved and anxious that the United States Government be advised of them as soon as possible. Dr. Szilard, who is one of the discoverers of the neutron emission of uranium on which all present work on uranium is based, described to me a specific system which he devised and which he thought would make it possible to set up a chain reaction in unseparated uranium in the immediate future. Having known him for over twenty years both from his scientific work and personally, I have much confidence in his judgment, and it was on the basis of his judgment as well as my own that I took the liberty to approach you in connection with this subject. You responded to my letter dated August 2, 1939 by the appointment of a committee under the chairmanship of Dr. [Lyman] Briggs and thus started the Government's activity in this field.

The terms of secrecy under which Dr. Szilard is working at present do not permit him to give me information about his work; however, I understand that he now is greatly concerned about the lack of adequate contact between scientists who are doing this work and those members of your Cabinet who are responsible for formulating policy. In the circumstances, I consider it my duty to give Dr. Szilard this introduction and I wish to express the hope that you will be able to give his presentation of the case your personal attention.

Very truly yours, A. Einstein

Roosevelt died April 12, 1945, of a cerebral hemorrhage. He probably never saw this letter.

Sources: fdrlibrary.marist.edu; dannenberg.com; hypertextbook.com/eworld/einstein.shtml; http://www.mphpa.org/classic/COLLECTIONS/MP-Einstein~Sachs/Pages/Ein-Sachs_Gallery_01.htm; and Lanouette with Szilard, *Genius in the Shadows*, pp. 261–262, for exchanges of letters on the matter; Alexander Sachs, "Early History of the Atomic Project in Relation to President Roosevelt, 1939–40: From Inception to Presentation of Idea by Albert Einstein and Alexander Sachs," August 8–9, 1945, at Einstein Archives 39-488.1. See also Nathan and Norden, *Einstein on Peace*, pp. 292–306.

Postwar and Cold War, 1946–1955

The solution to the dilemma of disarmament at the end of the Second World War seemed obvious to Einstein: "The secret of the [atomic] bomb should be committed to a world government, and the United States should immediately announce its readiness to do so" ("On the Atomic Bomb, as told to Raymond Swing," *Atlantic Monthly*, November 1945, pp. 43–45). In late 1945, the Soviets did not yet possess an atomic weapon, though they had been working feverishly on one in secret. It thus appeared possible by introducing confidence-building measures to convince the Russians that a world government would guarantee their security. That this was illusory would soon be demonstrated, though Einstein steadfastly continued to argue that a world at peace could only be achieved by ridding all countries of their military

establishments and the arms that provided their *raison d'être*. (See Organizational Ties, "Emergency Committee of Atomic Scientists"; Pacifism; and World Government, *below*.)

Fear of the Soviet Union and communism gripped the United States after the Soviets detonated their first atomic bomb in September 1949. As Cold War tensions deepened, Einstein's confidence in the American political system waned. Recalling how liberal democracy had come under a similar attack in Germany, thereby enabling Hitler "to deal it the death-blow with ease," he predicted that the same would happen in the United States "unless men with vision and willingness to sacrifice come to the defense" (see letter to Norman Thomas, March 10, 1954; Einstein Archives 61-549). The sharp crackdown on those whose activities betrayed a lack of firm allegiance to the American way of life was, in his eyes, a form of ideological tyranny: "The fear of Communism has led to practices which have become incomprehensible to the rest of civilized mankind and exposed our country to ridicule" (Human Rights, February 20, 1954; Einstein Archives 28-1012).

Although he was spared the ignominy of having to testify before the House Un-American Activities Committee (HUAC) or Senator Joseph McCarthy's Permanent Investigations Subcommittee, in 1953 Einstein lashed out publicly against such inquisitorial methods: "What ought the minority of intellectuals to do against this evil? Frankly, I can see only the revolutionary way of non-cooperation in the sense of Gandhi's. Every intellectual who is called before one of the committees ought to refuse to testify, i.e., must be prepared for jail and economic ruin, in short, for the sacrifice of his personal welfare in the interest of the cultural welfare of his country" ("Open Letter to William Frauenglass," *New York Times*, June 12, 1953; see no. 202 in [appendix C](#)). The *Times* itself featured an editorial the following day that took harsh issue with Einstein's position, saying it would be "most unwise ... [t]o employ the unnatural and illegal forces of civil disobedience" in an attempt "to attack one evil with another" (Nathan and Norden, *Einstein on Peace*, p. 550). (See also Civil and Human Rights, *above*.)

FBI'S EINSTEIN FILE

Twenty-five years after Einstein's death, the FBI revealed that J. Edgar Hoover had been keeping a secret file on Einstein's political activities at least since the early 1930s. The reasons were that Einstein had been seen alongside Communists attending pacifist meetings, and he had supported the republican cause in Spain during the Spanish Civil War. Einstein had not been aware of this intrusion into his privacy, which lasted until his death. The 1,427 pages of material, no longer classified, are available online in fourteen parts at <http://vault.fbi.gov/Albert%20Einstein>.

The file consists of a dossier filled with memos from FBI agents to one another about what the "subject" or "captioned individual" had been up to. There are notes and observations about meetings Einstein attended and organizations that listed him as a member. Most documents in fact indicate that he was neither a Communist nor "subversive," yet the file remained active. Already in September 1933, shortly before leaving Europe for good, he had publicly explained his view on communism in a letter to the *London Times*, stating that he had never favored communism and did not favor it now (see no. 144 in [appendix C](#)). In a letter of July 26, 1940, about two months before Einstein became an American citizen, he was denied security clearance by Brigadier General George Strong. The FBI was not the first or only organization interested in Einstein's activities: the Germans had also spied on him (see Grundmann's *The Einstein Dossiers*, discussed in [appendix A](#), "Specialized Books").

In all of the classified memos, some words and passages are blocked out, most likely to protect innocent people who were still alive. An assortment of rubber-stamped locutions warn the reader that this page is "secret" or "confidential," though these words were crossed out when the file was declassified. In addition, copies of dozens of newspaper clippings that cover Einstein's activities are included for the record. Some samples of the file's entries follow.

A memo discusses the "Committee of 1,000," the plan of Harlow Shapley of Harvard to recruit one thousand prominent Americans, including Einstein, in a drive to abolish the House Un-American Activities Committee (HUAC).

A memo discusses *Counterattack*, a weekly newsletter published by the American Business Consultants Inc. of New York. It ran an article about a meeting of the

American Committee of Jewish Writers, Artists, and Scientists, which it claimed was a Communist-front organization, and maintained that Einstein had allowed himself to be “roped” into it.

A memo claims Einstein made the following statement in December 1947: “I came to America because of the great, great freedom which I heard existed in this country. I made a mistake in selecting America as a land of freedom, a mistake I cannot repair in the balance of my life.”

Files dated February 13 and 15, 1950, state that Einstein had no formal security clearance from the Atomic Energy Commission or the Manhattan Engineer District, a fact that would confirm that Einstein could not have worked on the atom bomb project. One of the memos maintains that “the Bureau files fail to reflect that any investigation has ever been conducted on Professor Einstein for any purpose whatsoever.”

The memo then states that Einstein was affiliated in “some way or other” with at least thirty-three organizations that were listed by the attorney general, HUAC, or California HUAC as Communist organizations. He was also affiliated with fifty organizations that were not so listed. “He is principally a pacifist and could be considered a liberal thinker as indicated by his connections with the various organizations indicated above.”

The file notes that Einstein is sympathetic to Russian scientists and sympathizes with the Soviet Union. Supplementary handwritten notes mention that Einstein’s son is in Russia. Another memo quotes an informant as saying that Elsa Einstein was “scared to death” over the fact that son Hans Albert was in the Soviet Union around 1944 and might be held hostage there to force Einstein into some particular action. (Elsa had died in 1936. There is no record that Hans Albert, her stepson, was in the USSR at the time, or any other time. No doubt, Hans Albert had been confused with the Russian émigré Dmitri Marianoff, Elsa’s son-in-law.)

A memo of March 13, 1950, claims that Einstein’s office in Berlin had been used as a telegram address for Soviet Comintern agents and other Soviet apparatchiks in the early 1930s, before he left Germany, and that he had hired a group of typists and secretaries who were Soviet sympathizers. (In fact, Helen Dukas was his only secretary at the time.) The memo states that one of Einstein’s secretaries turned over the telegrams (“conspirative correspondence”) to a special “apparat man” (a Soviet courier) who also picked up telegrams at other designated addresses. Einstein’s address was considered a useful cover for a letter drop because he received telegrams from all over the world. The telegrams were in code, and it was assumed Einstein did not know their contents. (Siegfried Grundmann, as reported in his book *The Einstein Dossiers*, carefully examined these allegations and concluded that they were unfounded.)

A memo of September 14, 1950, states that “this naturalized person, notwithstanding his worldwide reputation as a scientist, may properly be investigated for possible revocation of naturalization.... It appears that appropriate investigation for that purpose is warranted.” This investigation was warranted because of the alleged Soviet use of Einstein’s address in Berlin.

A memo of October 23, 1950, from J. Edgar Hoover himself, requests that Helen Dukas be investigated for “past activity on behalf of the Soviet Union” (that is, while serving as Einstein’s secretary in Berlin).

Later memos fault Einstein for allowing Paul Robeson to deliver Einstein’s letter to President Harry Truman stating his opposition to lynching. Robeson was chairman of the American Crusade to End Lynching, an alleged Communist-front organization. Another memo lists “Indicators of Einstein’s Sympathy with the Communist Party.”

See also R. A. Schwartz, “Einstein and the War Department,” *Isis* 80 [1989], 281–284, and Fred Jerome, *The Einstein File*, for a thorough discussion.

THE RUSSELL-EINSTEIN MANIFESTO

During the last months of his life, Einstein was directly involved in a new political effort aimed at overcoming the impasse that separated East and West. With the advent of the hydrogen bomb in 1952, the threat of nuclear disaster loomed larger than ever. This circumstance prompted Bertrand Russell to make a worldwide effort to avert catastrophe by means of a widely publicized statement issued in his and Einstein’s names. The Russell-Einstein Manifesto called for the governments of the

world “to acknowledge publicly, that their purposes cannot be furthered by a world war” and “to find the peaceful means for the settlement of all matters of dispute between them” (Nathan and Norden, *Einstein on Peace*, p. 635). Although he did not live to see it publicized, just by lending his signature to this document Einstein helped bring public attention to these pressing political problems.

This document discussing the perils of a nuclear world was drafted by Bertrand Russell and signed by Einstein just days before his death in April 1955—it was Einstein’s last signed document. Other prominent intellectuals and scientists joined as signatories, and Russell released the statement at a press conference on July 9, 1955, in London in the midst of the Cold War. Within two years it led to the creation of the Pugwash Conferences on Sciences and World Affairs, in which scientists of all political persuasions assemble to discuss the threat posed to civilization by weapons of mass destruction. The conferences are still held annually. The manifesto is reprinted here in its entirety.

In the tragic situation which confronts humanity, we feel that scientists should assemble in conference to appraise the perils that have arisen as a result of the development of weapons of mass destruction, and to discuss a resolution in the spirit of the appended draft.

We are speaking on this occasion, not as members of this or that nation, continent, or creed, but as human beings, members of the species Man, whose continued existence is in doubt. The world is full of conflicts; and, overshadowing all minor conflicts, the titanic struggle between Communism and anti-Communism.

Almost everybody who is politically conscious has strong feelings about one or more of these issues; but we want you, if you can, to set aside such feelings and consider yourselves only as members of a biological species which has had a remarkable history, and whose disappearance none of us can desire.

We shall try to say no single word which should appeal to one group rather than to another. All, equally, are in peril, and, if the peril is understood, there is hope that they may collectively avert it.

We have to learn to think in a new way. We have to learn to ask ourselves, not what steps can be taken to give military victory to whatever group we prefer, for there are no longer such steps; the question we have to ask ourselves is: what steps can be taken to prevent a military contest of which the issue must be disastrous to all parties?

The general public, and even many men in positions of authority, have not realized what would be involved in a war with nuclear bombs. The general public still thinks in terms of the obliteration of cities. It is understood that the new bombs are more powerful than the old, and that, while one A-bomb could obliterate Hiroshima, one H-bomb could obliterate the largest cities, such as London, New York, or Moscow.

No doubt in an H-bomb war great cities would be obliterated. But this is one of the minor disasters that would have to be faced. If everybody in London, New York, and Moscow were exterminated, the world might, in the course of a few centuries, recover from the blow. But we now know, especially since the Bikini test, that nuclear bombs can gradually spread destruction over a very much wider area than had been supposed.

It is stated on very good authority that a bomb can now be manufactured which will be 2,500 times as powerful as that which destroyed Hiroshima. Such a bomb, if exploded near the ground or under water, sends radio-active particles into the upper air. They sink gradually and reach the surface of the earth in the form of a deadly dust or rain. It was this dust which infected the Japanese fishermen and their catch of fish.

No one knows how widely such lethal radio-active particles might be diffused, but the best authorities are unanimous in saying that a war with H-bombs might possibly put an end to the human race. It is feared that if many H-bombs are used there will be universal death, sudden only for a minority, but for the majority a slow torture of disease and disintegration.

Many warnings have been uttered by eminent men of science and by authorities in military strategy. None of them will say that the worst results

are certain. What they do say is that these results are possible, and no one can be sure that they will not be realized. We have not yet found that the views of experts on this question depend in any degree upon their politics or prejudices. They depend only, so far as our researches have revealed, upon the extent of the particular expert's knowledge. We have found that the men who know most are the most gloomy.

Here, then, is the problem which we present to you, stark and dreadful and inescapable: Shall we put an end to the human race; or shall mankind renounce war? People will not face this alternative because it is so difficult to abolish war.

The abolition of war will demand distasteful limitations of national sovereignty. But what perhaps impedes understanding of the situation more than anything else is that the term "mankind" feels vague and abstract. People scarcely realize in imagination that the danger is to themselves and their children and their grandchildren, and not only to a dimly apprehended humanity. They can scarcely bring themselves to grasp that they, individually, and those whom they love are in imminent danger of perishing agonizingly. And so they hope that perhaps war may be allowed to continue provided modern weapons are prohibited.

This hope is illusory. Whatever agreements not to use H-bombs had been reached in time of peace, they would no longer be considered binding in time of war, and both sides would set to work to manufacture H-bombs as soon as war broke out, for, if one side manufactured the bombs and the other did not, the side that manufactured them would inevitably be victorious.

Although an agreement to renounce nuclear weapons as part of a general reduction of armaments would not afford an ultimate solution, it would serve certain important purposes. First, any agreement between East and West is to the good in so far as it tends to diminish tension. Second, the abolition of thermo-nuclear weapons, if each side believed that the other had carried it out sincerely, would lessen the fear of a sudden attack in the style of Pearl Harbour, which at present keeps both sides in a state of nervous apprehension. We should, therefore, welcome such an agreement though only as a first step.

Most of us are not neutral in feeling, but, as human beings, we have to remember that, if the issues between East and West are to be decided in any manner that can give any possible satisfaction to anybody, whether Communist or anti-Communist, whether Asian or European or American, whether White or Black, then these issues must not be decided by war. We should wish this to be understood, both in the East and in the West.

There lies before us, if we choose, continual progress in happiness, knowledge, and wisdom. Shall we, instead, choose death, because we cannot forget our quarrels? We appeal as human beings to human beings: Remember your humanity, and forget the rest. If you can do so, the way lies open to a new Paradise; if you cannot, there lies before you the risk of universal death.

RESOLUTION

We invite this Congress, and through it the scientists of the world and the general public, to subscribe to the following resolution:

"In view of the fact that in any future world war nuclear weapons will certainly be employed, and that such weapons threaten the continued existence of mankind, we urge the governments of the world to realize, and to acknowledge publicly, that their purpose cannot be furthered by a world war, and we urge them, consequently, to find peaceful means for the settlement of all matters of dispute between them."

[Signed by]

Max Born, Percy W. Bridgman, Albert Einstein, Leopold Infeld, Frédéric Joliot-Curie, Hermann J. Muller, Linus Pauling, Cecil F. Powell, Joseph Rotblat, Bertrand Russell, Hideki Yukawa

Political Philosophy

Pacifism

As is true for all his political reflections, Einstein's pacifism can best be understood as the function of a moral stance rather than of a particular political commitment. It was for him "an instinctive feeling, a feeling that possesses me because the murder of men is disgusting. My attitude is not derived from any intellectual theory but is based on my deepest antipathy to every kind of cruelty and hatred" (see letter to Paul Hutchinson, July 1929, reprinted in Nathan and Norden, *Einstein on Peace*, p. 98). His stance also assumed a number of guises over time. Eight months after the outbreak of the First World War, in March 1915, he joined a short-lived pacifist organization, the Bund Neues Vaterland (Association for a New Fatherland; see Organizational Ties). Yet his apparent indifference at the time to military applications of his occasional work on a gyrocompass and on airplane design belies the persistent myth that he was a consistent and avowed pacifist (for a discussion of the tension between Einstein's pacifist stance and his lack of concern about military applications of his own work, see Fölsing, *Albert Einstein*, pp. 446–449). Nowhere are the motives for an emotional embrace of pacifism more apparent than during his first visit to Germany's western neighbor after the war, in April 1922. Repulsed by the sight of the destroyed villages and battlefields of eastern France, he urged that all students, German or otherwise, be brought there to witness the horror of war (fig. 42).



FIGURE 42. Viewing a village destroyed in the First World War near Dormans in northeastern France. The photo was taken on April 9, 1922. (*L'Illustration* [Paris], April 15, 1922; Library of Congress)

Buoyed initially by the possibility of an agreement to halt the arms race during the World Disarmament Conference in the early thirties, Einstein argued that governmental initiatives should be supplemented by voluntary associations of concerned citizens ("Statement on a Kellogg League," July 1931, in Lief, ed., *The Fight*

against War, p. 42). A more brazen proposal was his so-called two-percent solution, in which he assumed that governments would be helpless and prison systems would collapse “if only two percent of those supposed to perform military service should declare themselves war resisters” (address to the New History Society, “The Two Percent Speech,” December 14, 1930, in New York City; see Rowe and Schulmann, *Einstein on Politics*, p. 240). The failure of the great powers to come to an agreement was a severe blow to his hopes for unilateral pacifism. Yet he had already grown wary of the not-so-secret rearmament on all sides that lay at the heart of this failure. After Hitler came to power (fig. 43), Einstein realized that he had to change tack: “I am still of the opinion that to make war impossible is one of the most important goals of humanity. On the other hand, I recognized that refusal of military service could not be endorsed any longer since in certain countries the resistance to compulsory military service became impossible ... The only means to reach [the pacifist] goal is, in my opinion, an international organization for the enforcement of military security for the whole world” (see letter to John G. Moore, March 30, 1942; Einstein Archives 123-384).



FIGURE 43. “Einstein takes up the sword,” published in *The Brooklyn Eagle*, 1933, after Einstein abandoned his earlier pacifist stance upon learning of Hitler being granted emergency powers in Germany in March 1933 following the Reichstag fire a month earlier. (Drawing by Charles Raymond Macauley. Library of Congress LC-USZ62-42467)

In the face of the Cold War rivalry between the United States and the Soviet Union, Einstein refined his pacifist message once more. Believing that advances in military technology, such as atomic weaponry, had altered the rules of the game, he pleaded for an effective world government as necessary for survival: “Do I fear the tyranny of a world government? Of course I do. But I fear still more the coming of another war” (“On the Atomic Bomb, as told to Raymond Swing,” *Atlantic Monthly*, November 1945, pp. 43–45). To implement this vision, Einstein allowed himself to be appointed chair of the Emergency Committee of Atomic Scientists in autumn 1946 and began actively campaigning for an international framework for the control of nuclear energy (see *Organizational Ties*). With the advent of the hydrogen bomb in 1952, the threat of nuclear disaster loomed larger than ever. This circumstance prompted Bertrand Russell to issue a statement in his and Einstein’s names, and those of other prominent scientists, calling for the redoubling of efforts to avert catastrophe. Einstein did not live to see its publication. (See *Russell-Einstein Manifesto*, *above*.)

Socialism

Initially an advocate of the laws of supply and demand for distributing economic goods, Einstein came to regret this position, arguing in 1944 that a certain amount of compulsion, organization, and bureaucracy was necessary to provide for the material and intellectual needs of a society. The economic malaise following the Great Depression had convinced him that the ill effects on society of unchecked egoism and competition had to be balanced by the “limiting and regulative force” of the state in order to keep competition among workers within healthy limits (“Production and Work” [September 22, 1932], in *Ideas and Opinions*, pp. 92–93). His primary critique of capitalism was its negative potential for directing individuals’ energies away from the full development of their creative powers. This in turn would inhibit innovative contributions to the public good—a feature, he believed, that capitalism ironically shared with its diametric opposite: the antidemocratic, bureaucratic Soviet state.

In his essay, “Why Socialism?” (*Monthly Review*, an *Independent Socialist Magazine* 1, no. 1 [May 1949], pp. 9–15), written at an early stage of the Cold War, he indicted “the oligarchy of private capital” while arguing for a planned economy as a means for achieving equitable ends. Socialism maximized material benefits to each member of society, though it was vulnerable, he thought, to the creation of a powerful bureaucracy that could encroach upon individual rights. Einstein’s embrace of socialism was as a social-ethical philosophy, not a political-economic ideology. Nor did he conceive of socialism as a placebo, or as “the solution to all social problems, but merely as a framework within which such a solution is possible” (“A Reply to the Soviet Scientists,” *Bulletin of the Atomic Scientists*, December 1947, pp. 35–37; reprinted in *Out of My Later Years*, pp. 169–175).

A central contradiction in Einstein’s socialist views is that he was not a convinced egalitarian but rather more of an elitist. While frequently demonstrating philosophical sympathy for socialism with a human face, including many of its economic principles, as a nineteenth-century liberal he never identified with the intellectual tradition of the European labor movement or its Marxist legacy. As he unabashedly proclaimed in 1930: “what is truly valuable in our bustle of life is ... the creative and impressionable individuality, the personality—he who produces the noble and sublime while the common herd remains dull in thought and insensible in feeling” (“What I Believe”; see the frontmatter, *Credo*, for the full essay). These are scarcely the words of someone wedded to the tenets of class struggle.

World Government

Einstein first used this term in anticipation of the Disarmament Conference of 1932, when he declared that the abolition of war could only succeed through the surrender of a portion of each nation’s sovereignty in favor of an international body. After the Second World War, this became the touchstone of his political philosophy. The catastrophes of Hiroshima and Nagasaki and the publication of Emery Reves’s book, *The Anatomy of Peace*, in particular, spurred Einstein to initiate a campaign not only to control nuclear weapons but to build the framework for a world government with enough power and authority to contain national military conflicts and violence. Einstein particularly seized on Reves’s criticism of “all the wrong steps already taken

(secrecy in armament under purely national viewpoints, especially about the production of the atomic bomb, occupation of strategic parts of the Pacific under exclusive U.S.A. control)” (see letter to Emery Reves, August 28, 1945; Einstein Archives 57-292).

An interview given to a sympathetic ABC correspondent, Raymond Gram Swing, and published in the *Atlantic Monthly* in November 1945, provides the most pointed public exposition of his views (see nos. 178 and 183 in [appendix C](#)). Beginning from the premise that war is inevitable as long as there are sovereign nations possessing great power, Einstein argued that with the advent of atomic weapons, only the commitment of all military resources to a world government might avoid otherwise inevitable warfare. Outlawing war itself, as suggested by Linus Pauling among others, he thought to be “ineffective. Even if it would be possible to create a mass movement with this slogan, it is clear that one cannot prevent competitive armament and the danger of war without a kind of world government of sufficient strength and independence” (see letter to Linus Pauling, June 8, 1954; Einstein Archives, 60-874). He proposed that the three great powers—the United States, Soviet Union, and Great Britain—draft a constitution for such a government and after its adoption encourage smaller nations to join. In addition to military jurisdiction, a world government should also have the power to interfere in countries where a minority was oppressing the majority, thereby creating the kind of instability that leads to war. While acknowledging the possibility of a tyrannical world government, Einstein feared another war even more. In a letter to his best friend the following spring, he explained that, though it was a shame to waste “much energy on the meager soil of politics,” it was important to inform the public of “the necessity of a world government, without which all our human grandeur will go to the dogs” (see letter to Michele Besso, April 21, 1946; Einstein Archives, 7-381).

The Soviet Union’s rejection of the Baruch Plan of 1946, an American proposal to reinforce its atomic monopoly, scarcely slowed Einstein’s resolve. In an “Open Letter to the General Assembly of the United Nations,” published October 1947, he called on the United States, with or without the Soviet Union, to work for reforms that would strengthen the organization with an eye toward a future world government. Only thus could its moral authority be strengthened by bold decisions and could the security, tranquility, and the welfare of all mankind be guaranteed. He stated further that the authority of the General Assembly should be increased, so that the Security Council is subordinate to it; delegates should be elected directly by the people and not by governments; and the General Assembly should remain in session during the period of transition. With the failure of the Baruch Plan, however, the die was cast, and the United States and the Soviet Union embarked on programs of relentless weapons development, innovation, production, and testing as part of the overall nuclear arms race of the Cold War.

Religion

Einstein’s views on this subject are contained in his credo of October 1930 in the essay “What I Believe” (see the frontmatter for the full essay). At the source and heart of all religious experience is the mysterious: “To know that what is impenetrable to us really exists, manifesting itself as the highest wisdom and the most radiant beauty which our dull faculties can comprehend only in their most primitive forms—this knowledge, this feeling, is at the center of true religiousness. In this sense, and in this sense only, I belong in the ranks of devoutly religious men.”

With Spinoza, he rejected the idea of a transcendent God, believing that Nature and God are one and the same, an identity that he termed a “pantheistic” point of view. His dismissal of traditional religion was sharp-edged and to the point: “I can only view confessional traditions historically and psychologically; I have no other relationship to them” (1922, in a reply to a YMCA member in Tokyo, *CPAE*, Vol. 13, Doc. 398; Einstein Archives 28-013). Similarly, he dismissed the idea of a punitive God, whom he considered to be a mere reflection of human frailty. The concept of an immortal soul he found utterly unconvincing, a product of man’s fear and egotism: “It is enough for me to contemplate the mystery of conscious life perpetuating itself through all eternity, to reflect upon the marvelous structure of the universe which we can dimly perceive, and to try humbly to comprehend even an infinitesimal part of

the intelligence manifested in nature.” (See the frontmatter, Credo: “What I Believe.”)

In addition to rejecting organized religion—he declared himself without religious affiliation already in the Swiss years—Einstein also rejected atheism, feeling that the intolerance of atheists is the same as that of religious fanatics, who “can’t hear the music of the spheres” (1941; Einstein Archives 54-927). In an interview with the *Saturday Evening Post* on October 26, 1929, he flatly stated “I am not an atheist,” but he did not know if he was a pantheist, either: “The problem involved is too vast for our limited minds.” Yet he believed there should be reason behind one’s beliefs: “Mere unbelief in a personal God is no philosophy at all” (letter to V. T. Altonen, May 7, 1952; Einstein Archives 59-059). Fundamentally, he declared, his stance on “God” is that of an agnostic: “I am convinced that a vivid consciousness of the primary importance of moral principles for the betterment and ennoblement of life does not need the idea of a law-giver, especially [one] who works on the basis of reward and punishment” (letter to Morton Berkowitz, October 25, 1950; Einstein Archives 59-215). In 1954, toward the end of his life, Einstein wrote a telling letter about his religious feelings to philosopher Eric Gutkind. Jewish religion, like all other religions, he wrote, “is the embodiment of the most childish superstition ... and the Bible a collection of honorable but still primitive, rather childish legends” (January 3, 1954; Einstein Archives 33-337). This handwritten letter, which contained further statements about his beliefs, was sold at auction in London in 2008 for more than \$400,000, twenty-five times the presale estimate.

Appendixes

Appendix A. Select Books and Documentaries

Being a modest person, desirous of privacy in personal matters, Einstein had no interest in writing a book-length autobiography. For some autobiographical reminiscences, however, see his “Autobiographical Notes” in Paul Schilpp, ed., *Albert Einstein: Philosopher-Scientist*, published in 1949—a contribution he referred to in jest as “my obituary.” Books such as *The World as I See It* and *Out of My Later Years*, though they sound autobiographical, are simply compilations of some of his thoughts and writings, most of which were assembled in 1954 in the popular anthology *Ideas and Opinions*. Einstein innately disliked the idea of a biography, especially one that discussed his personal life. He lamented to the writer Max Brod: “There have already been published by the bucketsful such brazen lies and utter fictions about me that I would long since have gone to my grave if I had allowed myself to pay attention to them” (February 2, 1949; Einstein Archives 34-066.1). That same year, however, his friend Philipp Frank published a biography of which Einstein approved.

Many authors have attempted to correct for Einstein’s own protective negligence in recording his life story. Here we present summaries of a sampling of our favorite and not-so-favorite biographies and other books and films available in English, listed alphabetically by the biographer’s last name. Some are scientific biographies, others are of a personal nature, and others are comprehensive and cover both. Even more books focus on a specific aspect of Einstein’s life or work. Early biographies—those published before the Einstein Archives were established and opened to researchers—are somewhat hagiographic. Most of the early editions are out of print, but some are still available from used-book sellers on the Internet.

Biographies

Brian, Denis. *Einstein, a Life*. New York: Wiley, 1996. After the much-praised biography by Abraham Pais appeared in 1982, in this book Denis Brian makes another attempt to jettison Einstein’s image as a superhuman being, a “Jewish saint.” With the help of the duplicate Einstein Archive at Boston University, he researched his subject well. His book does not include all the scientific information given by Pais, but it is better organized, more fluid, and, if somewhat chatty, more accessible to the general reader.

Bucky, Peter. *The Private Albert Einstein*. Kansas City: Andrews and McMeel, 1992. Bucky, the son of a close Einstein-family friend, Gustav Bucky, reminisces about his family’s encounters with Einstein.

Cassidy, David. *Einstein and Our World*. Atlantic Highlands, NJ: Humanities Press, 1995, 2004. Cassidy, a professor of natural sciences at Hofstra University, is a former associate editor of *The Collected Papers of Albert Einstein*. In this scholarly work, he focuses on the impact of Einstein’s scientific work on contemporary society.

Clark, Ronald W. *Einstein: The Life and Times*. New York: World Publishing, 1971. This was the first comprehensive and acclaimed biography of Einstein published after his death. It was so popular that it became a Book-of-the-Month Club selection, and editor and author Clifton Fadiman predicted that it would stand for some time as the standard biography of Einstein. It did so until Pais’s publication of “*Subtle Is the Lord*” in 1982. Clark, a writer and biographer of a number of outstanding public figures, was not yet able to make use of *The Collected Papers of Albert Einstein* and had gained limited access to the Einstein Archive at the Institute for Advanced Study. Clark, who was British, criticized Einstein’s fulminations against the British administration of Mandate Palestine. For a decade, the book had no competition, and much of what the general public knew about Einstein until 1981 was gleaned from this volume. It is still in print.

Fölsing, Albrecht. *Albert Einstein*. Trans. from German by Ewald Osers. New York: Viking, 1997. (This is a somewhat abridged edition of the German version.) Published one year after Denis Brian’s biography, this book was hailed as a more serious book by most Einstein devotees and scholars. First published in Germany and widely acclaimed there, its reputation had crossed the ocean before the long-awaited English

edition appeared. It became the favored biography until the publication of Walter Isaacson's book ten years later.

Frank, Philipp. *Einstein: His Life and Times*. Trans. George Rosen. New York: Alfred A. Knopf, 1947, 1953. Written by a friend of Einstein's who was a professor of physics at Harvard University, this book was one of the few well-researched biographies to appear in Einstein's lifetime. Frank covers Einstein's life as well as the physics of the first half of the twentieth century, with an emphasis on Einstein's scientific contributions. We cannot consider it a complete biography because much of the material contained in the Einstein Archives and *The Collected Papers of Albert Einstein* was not yet available to the author. It also lacks primary sources.

Highfield, Roger, and Paul Carter. *The Private Lives of Albert Einstein*. London: Faber and Faber, 1993 (U.S. edition, San Francisco: St. Martin's Press, 1994). This biography was written by two British editors who researched Einstein's family and romantic travails. They focus on Einstein's relationship with his first wife, Mileva, whom he had treated shabbily during the latter years of their marriage, though the two established a reasonable relationship after their separation. (See also Dennis Overbye's *Einstein in Love*, and Renn and Schulmann's *The Einstein/Maric Love Letters*.) The authors not only used extant biographical material but took pains to research new material, going directly to the people involved, including the editors of *The Collected Papers of Albert Einstein*. Its main drawback is that it is now more than twenty years old and lacks the latest scholarship.

Hoffmann, Banesh, with the collaboration of Helen Dukas. *Albert Einstein: Creator and Rebel*. New York: Viking, 1972. Hoffmann, an Einstein collaborator who helped make fundamental contributions to the theory of relativity, made a commendable effort to write about Einstein's early life and trace the scientific process that led to relativity theory. Though he did not have access to the complete Einstein Archive, the *New York Times* still claimed that "the exciting scientist is here in full measure," and *Publishers Weekly* called the book "compelling reading ... one of the most impressive books of the year."

Isaacson, Walter. *Einstein: His Life and Universe*. New York: Simon & Schuster, 2007. Isaacson's book seems to be on the bookshelves of most of our friends. Though it does not break new ground with insights into Einstein's life, the book has been highly praised by physicists and nonphysicists alike. In the respectful manner of an observer, Isaacson covers most topics about Einstein's life. He is a resourceful researcher who succeeded in gathering information from the best available sources. His portrayal of Einstein as embracing the American way of life after immigrating to the United States is exaggerated, however, as Einstein was quite critical of American society, especially of its materialism, its social inequality, its racism, and the vigilantism of the McCarthy era. Isaacson succeeded in marketing his book with the biggest media blitz ever undertaken for an Einstein book.

Marianoff, Dmitri, with Palma Wayne. *Einstein: An Intimate Study of a Great Man*. Garden City, NY: Doubleday, Doran, 1944. This book by the ex-husband of Einstein's stepdaughter Margot did not enjoy much acclaim after it was published, probably because Einstein made short shrift of it. Though he tries to show admiration and respect for Einstein, Marianoff, who was under suspicion of being a Russian spy both in Germany and in the United States, paints an unrealistic picture of the physicist, regarding him as remote and a dreamer and making no mention of humanitarian, political, and intellectual passions. The book is rife with poorly written family anecdotes and errors that give a view of Einstein's domestic life after his marriage to Elsa according to Marianoff's version of events. Einstein is said to have liked neither Marianoff nor his book, and called the latter "generally unreliable" and not worthy of publication.

Moszkowski, Alexander. *Conversations with Einstein*. Trans. from German by Henry L. Brose. New York: Horizon Press, 1970. These conversations between Einstein and the German-Jewish writer, philosopher, and satirist took place between 1916 and 1920 in Berlin and were first published in German in 1920 by F. Fontane & Co., Berlin. They were translated into English in 1921, and published in New York in 1922 by E. P. Dutton (reprinted in 1970 by Horizon). Though it is not strictly a biography, Moszkowski's book was the first of hundreds of books in many languages to record some aspects of Einstein's life. The fact that he revealed his personal thoughts and facts about his life in a series of conversations slated for publication proved to be controversial among Einstein's friends, particularly the German physicist Max Born

and his wife, Hedwig. They urged him to stop its publication in Germany for fear it would incite more anti-Semitism and further open him to allegations that he was a publicity seeker. This fear was understandable in the context of the right-wing anti-relativity campaign that was taking place in 1920, in which its adherents claimed that Einstein was a self-promoter and relativity was a fraud. Although he was not overly impressed with the manuscript, Einstein made only a lame attempt to stop its publication. In any case, neither the publisher nor the author would agree to cease publication, which had already proceeded. Later in life, Born read the book and concluded it was not as bad as he had feared. (See Fölsing's biography, pp. 469–471.)

Neffe, Jürgen. *Einstein*. Trans. from German by Shelley Frisch. New York: Farrar, Straus and Giroux, 2005. This well-translated biography was eclipsed by the simultaneous publication of Walter Isaacson's hugely popular and more widely marketed biography. This volume is organized thematically rather than chronologically, and does not skip over Einstein's "darker side." Neffe presents an interesting psychological picture of Einstein, especially vis-à-vis his relationships with women and his sons.

Pais, Abraham. *"Subtle Is the Lord": The Science and the Life of Albert Einstein*. Oxford and New York: Oxford University Press, 1982. This book is still the scientists' favorite Einstein biography. It is too technical and dense to be labeled a "popular" biography, but it is carefully researched, and one that fellow physicists claim Einstein would have liked the best. As someone who knew Einstein personally, Pais, a well-known physicist in his own right, was the first to impart an intimate, nonhagiographic account of Einstein's personal life, including some previously unknown personal facts. It became one of the *New York Times's* Best Books of the Year, and the winner of the 1983 American Book Award for Science. Still, the book is somewhat disorganized, as Pais tends to go off on tangents here and there. Like Stephen Hawking's *A Brief History of Time*, this is a book that everyone wanted to own but not many fully understood.

Reiser, Anton [Rudolf Kayser]. *Albert Einstein: A Biographical Portrait*. Trans. from German by Louis Zukovsky. New York: Boni, 1930. Written pseudonymously by Einstein's son-in-law, the husband of stepdaughter Ilse Einstein, this is an insider's look at Einstein. Reiser/Kayser traces Einstein's life from childhood through international celebrity, with firsthand family accounts serving as his sources. As Einstein wrote in 1931, he considered the book "in my opinion, the best biography that has been written about me. It comes from the pen of a man who knows me well personally" (letter to Edgar Magnin, February 25, 1931; Einstein Archives 47-569). He wrote a short introduction for it, purportedly to help boost its sales for Kayser and Ilse. Kayser was editor-in-chief of the Berlin monthly *Neue Rundschau* for many years. It is the earliest "real" published biography (as compared with Moszkowski's) that we could find in English. Since Einstein considered it "the best," perhaps there were others published in German.

Sayen, Jamie. *Einstein in America*. New York: Crown, 1985. This book, much overlooked by scholars and the general public, was written by the son of Einstein's neighbors on Mercer Street in Princeton. He presents a very readable, unpretentious, informative, and straightforward biography that includes information often missed by other biographers. Despite its title, the book covers more territory than just Einstein's life in the United States.

Specialized Books

There are far too many books on specific parts of Einstein's life and science to review here. The Einstein Papers Project offices at Caltech have accessioned some seven hundred such books in various languages, and, no doubt, there are even more—and there will be yet more by the time this book is published. Some books, such as Nigel Calder's *Einstein's Universe*, Jeremy Bernstein's *Einstein*, and Leopold Infeld's *Albert Einstein and The Evolution of Physics* (the latter coauthored with Einstein), were good in their day but are outdated now. Here, in no particular order, are some of the sourcebooks we have kept on our bookshelves. Publishers for some of the books can be found in the References section at the back of this book.

Einstein's *The Meaning of Relativity: Four Lectures Delivered at Princeton University, May 1921*, 5th edition (1954), based on the five lectures delivered at Princeton University in 1921, though in the volume they appear as only four. In his original

manuscript of the book in German, Einstein refers to his five lectures, but in the English version, the first two chapters were combined into one and the subtitle was changed to “four lectures.”

Einstein's *Ideas and Opinions*, trans. Sonja Bargmann, a compilation of short writings, published first in 1954 and reprinted regularly over the decades. Some of the essays vary from other translated originals. This book includes many of the essays featured in earlier publications, such as *Out of My Later Years*, *The World as I See It*, *Essays in Science*, and *Cosmic Religion*.

Albert Einstein, the Human Side (1979, 1981), short excerpts and quotations taken from Einstein's writings and correspondence and compiled by Helen Dukas and Banesh Hoffmann for the Einstein Centennial, published by Princeton University Press.

Albert Einstein/Mileva Maric: The Love Letters (1992), trans. Shawn Smith, edited by Jürgen Renn and Robert Schulmann, the annotated early letters between Einstein and his future first wife during their courtship and first year of marriage, dating from 1897 to 1903.

Einstein on Peace (1968), edited by Otto Nathan and Heinz Norden, a compilation of Einstein's political writings. This book has been superseded by the more comprehensive and updated *Einstein on Politics* (2007), edited by David E. Rowe and Robert Schulmann.

Einstein and Religion (1999) by Max Jammer, the only acceptable book-length discussion of Einstein's religious beliefs and the relationship between science and religion. Stay away from sources that describe Einstein as everything from mystical to atheistic.

Einstein's Miraculous Year: Five Papers that Changed the Face of Physics (1998, 2005), edited by John Stachel, the founding director and editor of *The Collected Papers of Albert Einstein*. These new translations of the papers that Einstein wrote during his annus mirabilis of 1905, annotated by Stachel, have been hailed in [amazon.com](https://www.amazon.com) reviews as “beautifully translated and edited,” with “the economy and freshness of Einstein's style [coming] through with undiminished force.” In *Einstein: 1905*, another fine book on the miraculous year published in 2005, John Rigden goes further to explain and discuss the contents of the five papers, though they are not reproduced in this book.

The American Learned Society's *The Concise Dictionary of Scientific Biography* (2000) is a useful abridged version of *The Complete Dictionary of Scientific Biography*, available online through the Gale Virtual Reference Library. The book contains biographical information on many of Einstein's colleagues and assistants.

John Stachel's *Einstein from B to Z* (2002) covers the lifework produced by the longtime Einstein scholar in a series of previously published scholarly articles on many subjects.

Albert Einstein: Philosopher-Scientist (1949 and later editions), edited by Paul Schilpp, part of the Library of Living Philosophers series. The book contains Einstein's “Autobiographical Notes,” presented face-to-face in German and English, a bibliography of Einstein's works, and many essays written by Einstein's contemporaries, including Louis de Broglie, Wolfgang Pauli, Max Born, Niels Bohr, Leopold Infeld, and Kurt Gödel. The “Autobiographical Notes” are also available separately in a small book produced by Open Court Publishers in 1979.

The Einstein Centennial of 1979 also stimulated the publication of many symposium volumes and anthologies, among them *Albert Einstein: Historical and Cultural Perspectives* (1981), edited by Gerald Holton and Yehuda Elkana, based on the centennial symposium held in Jerusalem; *Some Strangeness in the Proportion*, edited by Harry Woolf and based on the symposium held at the Institute for Advanced Study in Princeton; *Einstein: A Centenary Volume* (1979), edited by A. P. French, a comprehensive scholarly collection covering reminiscences about Einstein and discussions of his life and work, collected by the International Commission on Physics Education.

The year 2005 was the occasion for yet another anniversary—one hundred years had passed since Einstein published his theory of special relativity and experienced his annus mirabilis—and more celebratory volumes were published. Outstanding among these is *Albert Einstein, Chief Engineer of the Universe: One Hundred Authors for Einstein*, edited by Jürgen Renn, a former Einstein Papers Project editor who is currently a director of the Max Planck Institute for the History of Science in Berlin,

which conceived the project. The volume was first published in Germany to accompany an exhibition for the 2005 centennial year, and was translated into English for further worldwide distribution. The volume's title alludes to an infamous earlier book, *One Hundred Authors against Einstein*, which had been published in 1931 by scientists bent on denouncing Einstein and the theory of relativity. Einstein was nonplussed at the time and declared that to defeat relativity one did not need the words of one hundred scientists, but only one fact. The 2005 book is broad in its coverage, including one hundred essays by contributors with many cultural, academic, and scientific interests. It is also lavishly illustrated and beautifully produced.

Later, in 2008, Princeton University Press published another compilation of papers written by currently active Einstein scholars, *Einstein for the 21st Century*, edited by Peter Galison, Gerald Holton, and Silvan Schweber. The authors write about the relevance of Einstein to their own work and how his legacy might continue to influence future researchers.

The Cambridge Companion to Einstein, edited by Michel Janssen and Christoph Lehner, appeared in 2014 from Cambridge University Press. Fifteen scholars, two of whom are editors of the present volume, discuss aspects of Einstein's contributions in science, philosophy, and politics.

Einstein in Love: A Scientific Romance (2000), by *New York Times* science writer Dennis Overbye, depicts Einstein as a normal young man living during the first two decades of the twentieth century in Switzerland and Berlin, passionately pursuing his education, a career—and the woman who became his wife.

Einstein in Berlin (2003) by Thomas Levenson is another book that situates Einstein in Berlin during the eighteen years he spent in Germany's vibrant capital city, populated by artists, political radicals, self-styled intellectuals, and Europe's top scientists.

Einstein in Berlin (2005) by Hubert Goenner succeeds in capturing the ambience of Einstein's Berlin. Goenner is a physicist by training, but he has a real gift for portraying the social tensions that lay beneath the surface of the brilliant German capital. Unfortunately, the book is only available in the original German and in a Chinese translation (2012).

Fred Jerome's *The Einstein File* (2002) and *Einstein on Race and Racism* (2005) cover two topics that had been largely neglected until their publication. In the first book, Jerome looks inside Einstein's extensive FBI file. Over at least fifteen years, the FBI had created a 1,427-page file on Einstein because of J. Edgar Hoover's hateful obsession with Einstein and his belief that Einstein was a subversive. The goal was to identify Einstein as a traitor so his U.S. citizenship could be revoked, resulting in banishment from America. The second book (coauthored with Rodger Taylor) covers Einstein's lifelong interest in civil rights and puts his speeches, letters, and thoughts on the subject into context. The book is valuable for the letters it includes between Einstein and leaders of the black community.

Ze'ev Rosenkranz's *Einstein before Israel: Zionist or Iconoclast* (2011) focuses on Einstein's relationship with the Zionists of his day and makes extensive use of previously unpublished archival material. Einstein, opposed to nationalism of any kind, eventually came to terms with the inevitability of establishing a Jewish homeland even though he did not agree with the founders' political agenda. Rosenkranz, together with Barbara Wolff, also published *Albert Einstein: The Persistent Illusion of Transience* (2007), which contains material and photographs from the Einstein Archives in Jerusalem and presents them with introductions to Einstein's scientific, personal, and political life. It is a handsomely produced, large-format book.

The Einstein Dossiers (2005) by Siegfried Grundmann is a well-researched and detailed book on Einstein's political activities during his "Berlin period" and includes portions of Einstein's FBI file as an appendix. It includes an abundance of espionage-related information gathered by the Germans and later by the FBI. It is a dense book, first published in German, but is a good sourcebook for fans of intrigue.

Einstein's Jury (2006) by Jeffrey Crellin is an excellent book that traces the race to prove general relativity theory and the many setbacks the expeditions endured until they accomplished their task in 1919, catapulting Einstein to worldwide fame. The jury here consisted of the skeptical astronomers whose area of expertise was about to change radically. This is a good read for general relativity enthusiasts.

China and Albert Einstein (2005) by Danian Hu enriches the Einstein Studies genre by informing us about a heretofore-neglected area of inquiry: how Einstein and relativity theory were received by the largest Asian nation, and how its physicists, and its government, responded to it. We learn that in later times, during the Cultural Revolution of 1966–1976, Einstein’s theories, as well as his ideas on democracy and international peace, were disparaged, but they reemerged as the nation became more pragmatic in its economic pursuits.

In *Einstein in Spain* (1988), Thomas Glick discusses the period around which Einstein visited Spain (1923) and how the visit stimulated scientific discussion, even among those previously not interested in the sciences.

Einstein on the Road (2011) by Josef Eisinger traces Einstein’s extensive foreign travels during the 1920s, ending with his immigration to America in 1933. Einstein kept meticulous travel journals while at sea and on land, recording his observations of peoples and cultures with wit and sometimes with awe, especially during his voyage to the Far East. The diaries themselves are not reproduced in full, but some of them are in volume 13 of *The Collected Papers of Albert Einstein*.

Albert Meets America (2006) by József Illy, an editor at the Einstein Papers Project, is a detailed record of Einstein’s first journey to the United States in 1921 on a fund-raising trip for the Hebrew University of Jerusalem. It focuses on the media’s obsession with Einstein, who only two years earlier had spiraled into fame after scientific expeditions had presented their proof of the general theory of relativity. All of the attention he received took Einstein by surprise, but he gamely joined in by joking with reporters and causing sensational headlines. Illy’s more recent book, *The Practical Einstein* (2012), is a useful guide to Einstein’s patents, inventions, and his experimental—as opposed to his theoretical—side.

A very nicely produced large-format coffee table book, Andrew Robinson’s *Einstein: A Hundred Years of Relativity* (2005) was produced for the one-hundredth anniversary of the special theory of relativity. Filled with Robinson’s own writing and contributions from eminent physicists such as Freeman Dyson and Philip Anderson, it is also pleasing to peruse because of its many illustrations, both in black and white and color.

Three books of correspondence—besides the Einstein-Marić love letters—have been published in English: *Letters to Solovine, 1906–1955*, was published in 1987; *The Born-Einstein Letters*, which were first published in 1971, appeared in a new edition in 2005; and the correspondence on absolute parallelism between Elie Cartan and Einstein, *Elie Cartan-Albert Einstein*, which appeared in 1979. (Robert Schulmann’s edition of Einstein’s correspondence with his friend Heinrich Zangger is available only in German; see References.)

On the lighter and somewhat bizarre side, we have Michael Paterniti’s amusing *Driving Mr. Albert* (2000), an unlikely road trip adventure with Dr. Thomas Harvey, the infamous pathologist who had excised Einstein’s brain during the autopsy—ostensibly for the sake of scientific study. Mr. Albert, in this case, is Einstein’s actual brain, famously stored in formaldehyde in a Tupperware container and/or Mason jar. Harvey, an elderly man who was then in his eighties, wanted to meet Einstein’s granddaughter, Evelyn, in California, and took the brain with him, intending to give a slice of it to Evelyn. He needed a chauffeur to get him there, however, and, due to a series of circumstances, Paterniti ended up with the job. Thanks to Paterniti’s easy and colorful way with words, the result is a hilarious if irreverent story.

Books on Einstein family members include Milan Popović’s *In Albert’s Shadow: The Life and Letters of Mileva Maric, Einstein’s First Wife* (2003); Elizabeth Roboz Einstein’s *Hans Albert Einstein* (1991) and Robert Ettema and Cornelia F. Mutel’s *Hans Albert Einstein: His Life as a Pioneering Engineer*, about Einstein’s older son (the first was written by his second wife, the second was coauthored by an expert in hydraulic engineering—a field in which Hans Albert was a leader—and a science writer); and Michele Zackheim’s *Einstein’s Daughter: The Search for Lieserl* (1999). Some of these books are not completely reliable but may provide context.

And, lest we forget, we have our own books on our shelves as well: Robert Schulmann’s *Einstein on Politics* and *The Einstein/Maric Love Letters*, both coedited volumes, have already been mentioned. Daniel Kennefick’s *Traveling at the Speed of Thought* (2007) tackles the subject of yet-unobserved gravitational waves—fluctuations in the shape of spacetime—and the debates about them that emerged after the publication of Einstein’s general relativity theory. Alice Calaprice’s books on

Einstein's quotations on a variety of topics have been translated worldwide. The fourth edition, *The Ultimate Quotable Einstein* (2010), is the final edition. Her other books include *The Einstein Almanac* (2005), a chronological bibliography of Einstein's writings put into historical context; *Dear Professor Einstein* (2005), a book of children's letters to Einstein (*see also below*); and *Albert Einstein: A Biography* (A Greenwood Biography, 2005), written for young adults and coauthored with Trevor Lipscombe.

Children's Books

The best way to find a book about Einstein for children is to look at the amazon.com or Barnes & Noble listings of books for various age groups. We suggest sticking to the newer books that have been well reviewed by *School Library Journal* rather than choosing five-star selections, which are often based on sentimental parental perceptions of Einstein. Many of the older biographies are full of misinformation and fantasy and are not well produced. Some readers may wish to take a look at Calaprice's *Dear Professor Einstein: Einstein's Letters to and from Children* (2002), which is suitable for older children and parents. Besides the letters, it also includes an essay on Einstein's education by Robert Schulmann and a foreword by Einstein's granddaughter, the late Evelyn Einstein.

Documentary Films

A number of made-for-TV documentaries about Einstein were produced around the time of the one-hundredth anniversary of the special theory of relativity in 2005. Unfortunately, the definitive documentary has not yet been produced. All of the current films have a certain slant, whether it be Einstein's love life, his misogynistic tendencies, physics, his first wife Mileva's supposed coauthorship of relativity theory, Jewish identity, or the atom bomb. A look at online bookshops will bring up a dozen or so products in that genre. The most popular appear to be the Biography TV channel's version of Einstein's life, which concentrates on his personal life; the PBS presentations, *Einstein: The Private Thoughts of a Public Genius* (1979); *A. Einstein: How I See the World* (1991); and *Einstein Revealed* (1997), which contain some good video clips, though certain narrators' voices are quite over-the-top adulatory; and A&E TV's biography, which also contains some good archival footage.

Three Winters in the Sun: Einstein in California, produced by the University of Southern California's Annenberg Center in 2005, is an interesting interactive DVD-ROM that focuses on Einstein's time spent at Caltech in Pasadena in the early 1930s, covering six "communities" with which he interacted: Emigrés, the FBI, Hollywood, Household, Jews, and Science; it comes with its own little booklet. Interestingly, the Skirball Center in Los Angeles published *A Lone Traveler: Einstein in California*, by William M. Kramer, the year before (2004), but it is not related to the DVD.

Appendix B. Copyright, Licensing, and Permissions

As disclosed in his last will and testament (see [Part I](#), Death, “Last Will and Testament”), Einstein left his literary estate and all rights to it to the Hebrew University of Jerusalem (HUJI). The university therefore owns the copyright to Einstein’s writings, and those wishing to quote him in any way that is beyond “fair use” as defined by copyright law must obtain permission to do so. In 2025, that is, seventy years after his death, his writings will be in the public domain according to current U.S. Copyright law Sec. 302(a).

In recent years, the question of the use of his “image” for profit has been debated. The HUJI has maintained its own Einstein’s image as well as his writings. In 2012, a California federal judge dismissed a lawsuit filed by HUJI against General Motors (GM) for using a licensed but altered photograph of Einstein in an advertisement in 2009, ruling that, for a variety of legal reasons, Einstein’s “publicity rights” (use of his image) had fallen into the public domain fifty years after his death. Those interested in the details of the case or how it might apply to their own projects can read about it online at “Intellectual Property Law: Einstein Rights of Publicity” by Rebecca Gan. Vol. 31, no. 1 (January–February 2014) at

http://americanbar.org/publications/gp_solo/2014/january-february/intellectual_property_law_einsteins_rights_publicity.html; and “Einstein Publicity Rights Deemed Expired by California Federal Court” by Nancy D. Wolff and Nicholas J. Tariff. Posted in Legal Blog, Litigation, Trademarks, and Brands, October 17, 2012 at <http://cdas.com/einstein-publicity-rights-deemed-expired-by-california-federal-court/>.

For use of Einstein’s writings, including texts, such as letters he did not originally write for publication, individuals or institutions should contact the Einstein Archives at the Hebrew University of Jerusalem at <http://albert-einstein.org>. They will advise the user if HUJI or Princeton University Press (PUP) owns the rights to the material he or she wants to use. In general, PUP owns rights to all writings it published after 1971. A publications agreement between HUJI and PUP from that year signed over to PUP the first rights to publish his writings, which in effect means the writings in *The Collected Papers of Albert Einstein* published to date, and any spinoffs therefrom (for example, the *Einstein-Marić Love Letters*). HUJI itself is allowed to publish or allow third parties to publish or re-publish any texts that had already been published before 1971.

For photographs, users can go to a variety of sources to obtain photographs, all of them now easily found on the Internet. Among these are the American Institute of Physics in Maryland, the Caltech archives in Pasadena, HUJI/Albert Einstein Archives in Jerusalem, the Leo Baeck Institute in New York, the Lotte Jacobi Collection at the University of New Hampshire, Ullstein Photo in Berlin, and other photo archives found online, including Corbis and its subsidiary, GreenLight. These institutions and agencies will provide photographic scans for a fee (not all of them charge the same fee), but the photographer or his or her heirs, if known, must be contacted for permission (and any additional fees) to use the photos in case they are still protected by copyright laws not covered by the ruling discussed above. A good-faith effort, leaving a paper trail, must be made to find copyright owners. *The providers of the photographic scans are not necessarily also the copyright holders*, though sometimes they also represent the photographers or have information about them. In some cases, the photographers’ copyrights may have expired.

Individuals and institutions do not need the permission of Corbis or its subsidiaries, or of the HUJI/Albert Einstein Archives or Princeton University Press, to use photographs of Einstein for noncommercial and educational, scientific, academic, and documentary publications. If a prospective user is in doubt about whether a particular project qualifies, it is advisable to seek legal advice or contact HUJI.

For commercial use and licensing of Einstein paraphernalia and photographs, entrepreneurs and others should obtain legal advice to see if their proposed use falls

under the legal ruling discussed above. At the time of this writing, the GreenLight agency controls licensing rights for Einstein's image. See greenlightrights.com.

Appendix C. Select Annotated Bibliography

This chronological list of papers provides brief descriptions of the majority of Einstein's publications throughout his life. We did not include items we thought added little to our discussions of their themes in the relevant sections of the volume. In addition, we omitted Einstein's reviews of books and articles written by others—Einstein wrote many of these between 1902 and 1905 especially—as well as his brief comments on other scientists' articles and replies to comments about his own articles. The two best known of these are undoubtedly Einstein's objections, later withdrawn, to the two seminal papers on expanding-universe cosmologies by Willem de Sitter (1918) and Alexander Friedmann (1922). We also omit the various remembrances about fellow scientists and other intellectuals, unless they are particularly memorable. Only a few of his published letters to journals are listed.

Einstein wrote many papers on unified field theories (UFTs) from the mid-1920s on, but only a representative sample of these are included. The inclusion of all of his UFT papers would weight this bibliography too heavily toward this one aspect of his career that was relatively unsuccessful. His UFT program is summarized in [Part II](#), and some of his lesser-known papers on other topics are mentioned in the section on Scientific Sidelights, also in [Part II](#).

During his early career, Einstein wrote carefully crafted papers that were the last word on the topics they addressed. Later in life, he was more likely to publish updates of work in progress.

1901

1. "Conclusions Drawn from the Phenomena of Capillarity" (Folgerungen aus den Capillaritätserscheinungen). *Annalen der Physik* 4 (1901): 513–523. Einstein's first publication, dated December 13, 1900, but not published until the following March, discusses the phenomenon of capillarity in neutral liquids in studying the nature of intermolecular forces. The paper combines the use of both thermodynamic and molecular-theoretical methods.

1902

2. "On the Thermodynamic Theory of the Difference in Potentials between Metals and Fully Dissociated Solutions of Their Salts and on an Electrical Method for Investigating Molecular Forces" (Ueber die thermodynamische Theorie der Potentialdifferenz zwischen Metallen und vollständig dissociirten Lösungen ihrer Salze und über eine elektrische Methode zur Erforschung der Molekularkräfte). *Annalen der Physik* 8 (1902): 798–814. In this paper, Einstein discusses the conditions for the validity of the second law of thermodynamics, which became significant for his later work.
3. "Kinetic Theory of Thermal Equilibrium and of the Second Law of Thermodynamics" (Kinetische Theorie des Wärme Gleichgewichtes und des zweiten Hauptsatzes der Thermodynamik). *Annalen der Physik* 9 (1902): 417–433. Einstein fills the gap in the mechanical foundations of the "general theory of heat," demonstrating the validity of the equipartition theorem for any mechanical system. His mastery of this theorem would be a hallmark of his later approach to the quantum problem.

1903

4. "A Theory of the Foundations of Thermodynamics" (Eine Theorie der Grundlagen der Thermodynamik). *Annalen der Physik* 11 (1903): 170–187. Einstein shows that the concepts of temperature and entropy follow from the assumption of the energy principle and atomistic theory, assuming only the foundations of atomic physics and no other physical hypotheses. Among

other results, he shows that the second law of thermodynamics is valid for systems that are not in equilibrium, thus addressing many real-world systems that are not well described by conventional kinetic theory.

1904

5. "On the General Molecular Theory of Heat" (Zur allgemeinen molekularen Theorie der Wärme). *Annalen der Physik* 14 (1904): 354–362. This paper is the culmination of Einstein's efforts to generalize and extend the foundations of statistical physics and is his last paper devoted exclusively to the subject. Unknown to him, many of the ideas in these early papers had been anticipated by the reclusive American theorist Josiah Willard Gibbs. Einstein later remarked, "Had I been familiar with Gibbs's book at that time, I would not have published those papers at all, but would have limited myself to the discussion of just a few points" (CPAE, Vol. 3, Doc. 10).

1905

6. "On a Heuristic Point of View concerning the Production and Transformation of Light" (Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt). *Annalen der Physik* 17 (1905): 132–148. Here Einstein expounds on the peculiar discrepancy existing between material bodies and radiation. He introduces the concept of light quanta and provides the basis for much further work in quantum theory, especially Bohr's theory of the atom. He challenges the wave theory of light and shows that electromagnetic radiation interacts with matter as if the radiation has a granular structure, in describing the photoelectric effect. Einstein determined that a massless quantum of light, now called the photon, would have to impart the required energy according to Planck's radiation law, in order to break the attractive forces holding the electrons in the metal. This theory was one of the milestones in the development of quantum mechanics, making Einstein the foremost pioneer in the field and opening the world of quantum physics. The first of the five great papers he published in 1905, it was largely responsible for earning him the Nobel Prize in physics sixteen years later.
7. *A New Determination of Molecular Dimensions* (Eine neue Bestimmung der Moleküldimensionen). Bern: Buchdruckerei Wyss, 1906. Also slightly revised in *Annalen der Physik* 19 (1906): 289–305, which has an appended supplement on pp. 305–306, and an erratum in 34 (1911): 591–592. Here we have Einstein's doctoral dissertation, which he submitted to the University of Zurich in the spring of 1905 after withdrawing his first submission on a different topic in 1902. He combines the techniques of classical thermodynamics with those of the theory of diffusion to create a new method for determining molecular sizes. In proposing this work, he wanted to discover facts that would finally establish the existence of atoms of a precise finite size, since at the turn of the century the atom's existence was still in contention. The approval of this thesis earned Einstein his doctorate. Although overshadowed in fame by his other papers of 1905, this important work is still one of his more frequently cited papers.
8. "On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat" (Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen). *Annalen der Physik* 17 (1905): 549–560. Einstein discusses Brownian motion, the irregular movement of microscopic particles suspended in a liquid, named after the eighteenth-century Scottish botanist who first observed it. As Einstein explained in a letter to his friend Conrad Habicht, in this paper he proved that microscopic particles carry out an observable random movement, when suspended in a liquid, that is generated by the thermal motion of atoms in the fluid. By inverting Boltzmann's formula, Einstein describes its mathematics, deriving the probability of a macroscopic state for the

distribution of gas molecules. This paper led to experiments validating the kinetic-molecular theory of heat. This is still one of Einstein's most-cited papers and is often considered to be the most convincing demonstration of the reality of atoms.

9. "On the Electrodynamics of Moving Bodies" (Zur Elektrodynamik bewegter Körper). *Annalen der Physik* 17 (1905): 901–921. This important landmark in the development of physics is the first of Einstein's two papers that founded the theory of special relativity (the second is no. 10). Here he employs a modification of the theory of space and time. By assuming that the speed of light is the same to every observer who moves at a constant velocity, he showed that space and time are not independent, and spacetime was born. According to Hermann Weyl in 1918, this theory "led to the discovery that time is associated as a fourth coordinate on an equal footing with the other three coordinates of space, and that the scene of material events, the world, is therefore a four-dimensional, metrical continuum." It is arguably the most influential paper in all of twentieth-century physics, as its reformulation of kinematics has implications for essentially all fields of physics. Although the ideas developed in the paper were slowly emerging from the body of work on electromagnetic field theory, other theorists, even Henri Poincaré, failed to achieve Einstein's insight: that the results of the theory were not mere effects of the electromagnetic field, but rather limitations imposed on our ability to measure space and time because there was a finite speed by which information about distant events could reach us.
10. "Does the Inertia of a Body Depend upon Its Energy Content?" (Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?). *Annalen der Physik* 18 (1905): 639–641. Einstein uses the postulates of the special theory of relativity to show that energy radiated is equivalent to mass lost, which is expressed in the famous equation $E = mc^2$. He considers the conservation of energy of a radiating body in a system at rest and in a system in uniform motion relative to it. He concludes, for the first time, that "the mass of a body is a measure of its energy content." This work ultimately helped solve the vexing question of the source of the Sun's enormous energy output. The special theory of relativity paved the way for a deeper appreciation of symmetry criteria in physics and introduced new perceptions of space and time. Yet twenty-five years passed before experimental evidence in its favor emerged. Einstein credited Galileo, Newton, Maxwell, and Lorentz for laying the foundation for the theory.

1906

11. "On the Theory of Brownian Motion" (Zur Theorie der Brownschen Bewegung). *Annalen der Physik* 19 (1906): 371–381. Here Einstein presents his earlier ideas on Brownian motion in more elegant form, adding two new applications: the vertical distribution of a suspension under the influence of gravitation, and a calculation for a Brownian rotational movement for a rotating solid sphere.
12. "On the Theory of Light Production and Light Absorption" (Zur Theorie der Lichterzeugung und Lichtabsorption). *Annalen der Physik* 20 (1906): 199–206. Einstein argues that the fundamental concepts of mechanics and electrodynamics require drastic modification by quantum considerations, though in 1909 he reiterates that they should not be completely abandoned.
13. "The Principle of Conservation of Motion of the Center of Gravity and the Inertia of Energy" (Das Prinzip von der Erhaltung der Schwerpunktsbewegung und die Trägheit der Energie). *Annalen der Physik* 20 (1906): 627–633. In an ingenious thought experiment involving energy transport in a hollow cylinder, Einstein returns to the relationship between inertial mass and energy, giving general arguments for their complete equivalence. He shows that if light is transmitted from one end of the cylinder to the other, it could move the cylinder from the inside (in violation of our intuition based on Newton's third law) unless the light carries mass with it, and thus its change of position affects the location of

the cylinder's center of mass.

14. "On the Method for the Determination of the Ratio of the Transverse and Longitudinal Mass of the Electron" (Über eine Methode zur Bestimmung des Verhältnisses der transversalen und longitudinalen Masse des Elektrons). *Annalen der Physik* 21 (1906): 583–586. Einstein suggests an experimental test of the equations of motion of the electron using cathode rays.

1907

15. "Planck's Theory of Radiation and the Theory of Specific Heat" (Die Plancksche Theorie der Strahlung und die Theorie der spezifischen Wärme). *Annalen der Physik* 22 (1907): 180–190. He published a short erratum on p. 800 of the same journal. This is Einstein's first paper on the quantum theory of solids. In it, he makes a deduction of Planck's radiation formula, and it is the first systematic introduction of probability factors in the mathematics of quantum theory. A classic paper, it offered a complete explanation for the specific heat of solids from absolute zero to above room temperature. According to this theory, solids lose the ability to absorb heat altogether as their temperature approaches absolute zero. This influential paper would encourage the development of the third law of thermodynamics.
16. "On the Limit of Validity of the Law of Thermodynamic Equilibrium and on the Possibility of a New Determination of the Elementary Quanta" (Über die Gültigkeitsgrenze des Satzes vom thermodynamischen Gleichgewicht und über die Möglichkeit einer neuen Bestimmung der Elementarquanta). *Annalen der Physik* 22 (1907): 569–572. Einstein uses the thermodynamic approach to fluctuations in Brownian motion to predict voltage fluctuations in condensers. To test his theory, he needed a new, highly sensitive instrument—more sensitive than the available electrometers, which could measure only to a few thousandths of a volt. Einstein designed it, had it built, and famously called it his *Maschinchen* (little machine). He toyed with the idea of patenting it, but then dismissed the notion when manufacturers showed little interest. Instead, he decided to publish a paper on the basic features of the machine the following year.
17. "Theoretical Remarks on Brownian Motion" (Theoretische Bemerkungen über die Brownsche Bewegung). *Zeitschrift für Elektrochemie und angewandte physikalische Chemie* 13 (1907): 41–42. Einstein attempts to make the fundamental features of his theory accessible to readers with a moderate background in mathematics. He discusses some peculiarities of the statistical motion of suspended particles in a fluid that can hamper experimental verification.
18. "On the Possibility of a New Test of the Relativity Principle" (Über die Möglichkeit einer neuen Prüfung des Relativitätsprinzips). *Annalen der Physik* 23 (1907): 197–198. Einstein proposes a test of what has become known as the transverse Doppler effect, which is a direct measure of special relativistic time dilation. He shows that a particle moving transverse to the line of sight will still appear redshifted, but in an amount proportional to the square of its velocity, as opposed to the linear effect in the conventional Doppler shift observed when a body is moving along the line of sight.
19. "On the Inertia of Energy Required by the Relativity Principle" (Über die vom Relativitätsprinzip geforderte Trägheit der Energie). *Annalen der Physik* 23 (1907): 371–384. As in no. 13, Einstein discusses the relationship between inertial mass and energy, arguing for their complete equivalence, namely, every mass has an equivalent energy just as every form of energy has an equivalent mass. This relation maintains that a photon can convert into matter with the appropriate mass, and vice versa. He deduces the exact expression for the equivalence of mass and energy, that is, his celebrated equation $E = mc^2$. He also returns to the question of the impossibility of superluminal velocities.
20. "On the Relativity Principle and the Conclusions Drawn from It" (Über das Relativitätsprinzip und die aus demselben gezogenen Folgerungen). *Jahrbuch der Radioaktivität und Elektronik* 4 (1907): 411–462. Einstein

published some corrections to the paper the following year in vol. 5 (1908): 98–99. In this review article on relativity, Einstein summarizes the results of some of his earlier papers on the theory of relativity, sometimes simplifying his earlier proofs. It covers relativistic kinematics, optics, electromagnetic theory, and the relativistic dynamics of a particle and of an extended system. He proves that a body's inertial and gravitational masses are equal to the same quantity E/c^2 and therefore should be considered precisely equal to each other, the basis of the equivalence principle. This result would be the chief steppingstone to the 1915 theory on general relativity.

1908

21. "A New Electrostatic Method for the Measurement of Small Quantities of Electricity" (Eine neue elektrostatische Methode zur Messung kleiner Elektrizitätsmengen). *Physikalische Zeitschrift* 9 (1908): 216–217. Einstein published the basic features of his method for constructing the *Maschinen* that he used in his work on no. 16.
22. "Elementary Theory of Brownian Motion" (Elementare Theorie der Brownschen Bewegung). *Zeitschrift für Elektrochemie und angewandte physikalische Chemie* 14 (1908): 235–239. An elementary account of Einstein's theory of Brownian motion was needed, particularly by chemists who were trying to provide experimental support for it and often misunderstood it. Einstein elaborates especially on the relation between diffusion and osmotic pressure, and calculates the diffusion coefficient from the frictional resistance of the solvent fluid to the dissolved molecules.
23. "On the Fundamental Electromagnetic Equations for Moving Bodies" (Über die elektromagnetischen Grundgleichungen für bewegte Körper) (with Jakob Laub). *Annalen der Physik* 26 (1908): 532–540. A correction to this paper was published later in the year in vol. 27 (1908): 232, and a supplement the following year in vol. 28 (1909): 445–447. Elaborating on the relativistic transformation of Maxwell's vacuum equations discussed in no. 8, Einstein and Laub also consider the displacement vector **D** and the magnetic induction **B**. See also no. 24.
24. "On the Ponderomotive Forces Exerted on Bodies at Rest in the Electromagnetic Field" (Über die im elektromagnetischen Felde auf ruhende Körper ausgeübten ponderomotorischen Kräfte) (with Jakob Laub). *Annalen der Physik* 26 (1908): 541–550. Einstein wrote nos. 23 and 24 in a three-week period with Jakob Laub, his first scientific collaborator, to address the problems of formulating relativistically invariant equations for electromagnetic fields in moving media, first raised by Hermann Minkowski the year before.

1909

25. "On the Present Status of the Radiation Problem" (Zum gegenwärtigen Stand des Strahlungsproblems). *Physikalische Zeitschrift* 10 (1909): 185–193. In another article of the same title, written with Walter Ritz and published in the same volume, pp. 323–324, Einstein and Ritz summarize their differences on the radiation problem (Einstein advocates in that note the viewpoint that the preference for retarded electromagnetic potentials exhibited by physical systems is a consequence of the large number of charge particles in our universe. This viewpoint was later defined more concretely by the absorber theory of John Wheeler and Richard Feynman).
Responding to papers published by H. A. Lorentz, James Jeans, and Walter Ritz the preceding year in which they discussed their respective opinions on the radiation problem, Einstein elaborates the concept of the "statistical probability of a state" first introduced in no. 6. The new material includes the two arguments for the existence of light quanta based on the analysis of fluctuations in blackbody radiation. After making his first known attempt to find a field theory that would explain the structure of both matter and radiation, Einstein here admitted that he had not yet succeeded

in finding a system of equations for both. This attempt was a forerunner of his later search for a unified field theory.

26. "On the Development of Our Views concerning the Nature and Constitution of Radiation" (Über die Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung). *Deutsche Physikalische Gesellschaft, Verhandlungen* 7 (1909): 482–500. Also published the following month in *Physikalische Zeitschrift* 10 (1909): 817–825. Einstein had presented this lecture on September 21 at the 81st meeting of the Society of German Natural Scientists and Physicians held in Salzburg, Austria, the first such conference he attended. He summarized his views on radiation and for the first time publicly linked his work on relativity and the quantum hypothesis. This is the first synthesis showing the profound changes in the concept of light ushered in by the theory of relativity and of the important implications of this change on the development of physics. He reiterates that light, like matter, has an independent existence.

1910

27. "The Principle of Relativity and Its Consequences in Modern Physics" (Le principe de relativité et ses conséquences dans la physique moderne). *Archives des sciences physiques et naturelles* 29 (1910): 5–28, and 125–144. Published as two separate papers in the same journal and translated from German to French by Edouard Guillaume, this work is a general survey of the history and essence of the theory of relativity, along with its applications. In a letter to Jakob Laub dated August 27, Einstein stated that the paper did not contain any new insights, that it "merely comprises a rather general discussion of the epistemological foundations of the theory of relativity, no new views whatsoever, and almost nothing that is quantitative."
28. "On the Theory of Light Quanta and the Question of the Localization of Electromagnetic Energy" (Sur la théorie des quantités lumineuses et la question de la localisation de l'énergie électromagnétique). *Archives des sciences physiques et naturelles* 29 (1910): 525–528. Einstein presented this paper in May at a meeting of the Swiss Physical Society in Neuchâtel. Much of it is based on his earlier work on the quantum hypothesis, which could not be reconciled with the accepted theory of radiation.
29. "On the Ponderomotive Forces Acting on Ferromagnetic Conductors Carrying a Current in a Magnetic Field" (Sur les forces pondéromotrices qui agissent sur des conducteurs ferromagnétiques disposés dans un champ magnétique et parcourus par un courant). *Archives des sciences physiques et naturelles* 30 (1910): 323–324. Einstein presented this paper to a meeting of the Swiss Society for Natural Sciences in Basel on September 6, 1910. He discusses the question of a force exerted on a ferromagnetic substance in the presence of an external magnetic field, coming up with the only expression that satisfies the principle of action equals reaction.
30. "On a Theorem of the Probability Calculus and Its Application in the Theory of Radiation" (Über einen Satz der Wahrscheinlichkeitsrechnung und seine Anwendung in der Strahlungstheorie) (with Ludwig Hopf). *Annalen der Physik* 33 (1910): 1096–1104. Einstein and Hopf wrote this paper to show that the failure of statistical mechanics vis-à-vis the radiation law cannot be ameliorated by proposing that individual statistical events in the emission of light from different points on the surface of a luminous body are not actually independent but instead are interdependent with each other. Even if one assumes a failure to be statistically independent, one derives the same usual form of the radiation law as Fourier sum.
31. "Statistical Investigation of a Resonator's Motion in a Radiation Field" (Statistische Untersuchung der Bewegung eines Resonators in einem Strahlungsfeld) (with Ludwig Hopf). *Annalen der Physik* 33 (1910): 1105–1115. The authors make use of the results in no. 30, demonstrating that the Rayleigh-Jeans law of radiation is an unavoidable consequence of statistics, even if we avoid assumptions that we may think need correction. In other words, we cannot blame statistics for a faulty result.

32. "The Theory of the Opalescence of Homogeneous Fluids and Liquid Mixtures near the Critical State" (Theorie der Opaleszenz von homogenen Flüssigkeiten und Flüssigkeitsgemischen in der Nähe des kritischen Zustandes). *Annalen der Physik* 33 (1910): 1275–1298. Einstein explains the optical effects that occur near the critical point of a fluid (at which liquid and gas phases can coexist) and of a binary mixture of liquids that can also explain the blue color of the sky. It adds to earlier studies that provided evidence for the atomistic constitution of matter and is one of his most difficult papers to understand.

1911

33. "A Relationship between Elastic Behavior and Specific Heat in Solids with a Monatomic Molecule" (Eine Beziehung zwischen dem elastischen Verhalten und der spezifischen Wärme bei festen Körpern mit einatomigem Molekül). *Annalen der Physik* 34 (1911): 170–174. Einstein adds a comment on p. 590 of the same journal. To supplement Sutherland's observation that infrared eigenfrequencies of solid bodies possibly originate in the elastic vibrations of these bodies, Einstein adds that electrically charged ions are the source of optical vibrations while the mutual motions of the entire molecule cause elastic vibrations.
34. "Elementary Observations on Thermal Molecular Motion in Solids" (Elementare Betrachtungen über die thermische Molekularbewegung in festen Körpern). *Annalen der Physik* 35 (1911): 679–694. Here Einstein continues the work he had begun in 1907 on the specific heat of solids, where the heat agitation of solids was reduced to a monochromatic oscillation of the atom, and the specific heat was determined based on the quantum treatment of an oscillator in a radiation field. He explains the discrepancies between his formula and the measurements at low temperatures.
35. "On the Influence of Gravitation on the Propagation of Light" (Über den Einfluß der Schwerkraft auf die Ausbreitung des Lichtes). *Annalen der Physik* 35 (1911): 898–908. Einstein returns to his thoughts on gravitation and discusses his ideas on the static gravitational field, advancing the "half-shift" prediction of the deflection of light by a massive body such as the Sun. In his early papers on the subject (see also nos. 37 to 39), he used two important features: the principle of equivalence, and the role of the speed of light. In this paper he takes a broader perspective, saying that if a light beam is bent in an accelerating frame of reference, then (if the theory is correct) it must also be bent by gravity by exactly the equivalent amount.
36. "The Theory of Relativity" (Die Relativitätstheorie). *Naturforschende Gesellschaft in Zürich. Vierteljahrsschrift* 56 (1911): 1–14. A statement on the light quantum hypothesis was added in part 2 of the *Gesellschaft's Sitzungsberichte* of 1911, p. xvi. Einstein presented this paper at a meeting of the Zurich Society for Natural Sciences in January as a farewell lecture after resigning from the University of Zurich to go to Prague. For the first time, he used the term "relativity theory" in a paper, having felt earlier that "relativity principle" was a more accurate description. In the exposition of the concepts and principles of special relativity, this paper is similar to no. 27, though it is less technical.

1912

37. "Thermodynamic Proof of the Law of Photochemical Equivalence" (Thermodynamische Begründung des photochemischen Äquivalentgesetzes). *Annalen der Physik* 37 (1912): 832–838. A supplement was published in vol. 38 (1912): 881–884. Einstein presents a continuation of his earlier work on the interaction between light and matter and on photochemical processes. It contrasts with earlier work in that it makes no use of the quantum hypothesis. He demonstrates how what he calls "the law of photochemical equivalence" is deducible by purely thermodynamical arguments if one makes certain plausible assumptions. He wrote a

- supplement to the paper five months later in the same journal.
38. "The Speed of Light and the Statics of the Gravitational Field" (Lichtgeschwindigkeit und Statik des Gravitationsfeldes). *Annalen der Physik* 38 (1912): 355–369. Further exploring his studies of gravitation, based on the equivalence principle, Einstein sees with growing clarity that gravitation is intimately linked with the problem of the measurement of space and time.
 39. "On the Theory of the Static Gravitational Field" (Zur Theorie des statischen Gravitationsfeldes). *Annalen der Physik* 38 (1912): 443–458. Einstein more closely analyzes the equations of motion stated in no. 38, concluding that those equations cannot be reconciled with the given field equations for c (the speed of light, which played the role of the gravitational potential in this theory) because the principle of "action equals reaction" is violated. He modifies the field equation for c . The paper has the first rudimentary statement of the "law of the geodesics," which became important for the final formulation of the gravitation theory.
 40. "Is There a Gravitational Effect Which Is Analogous to Electrodynamical Induction?" (Gibt es eine Gravitationswirkung, die der elektrodynamischen Induktionswirkung analog ist?). *Vierteljahrsschrift für gerichtliche Medizin und öffentliches Sanitätswesen* 44 (1912): 37–40. This paper shows Einstein's first steps in going beyond his static theory as he proceeded systematically from the special to the more general theory of relativity. In discussing the possibilities of effects of a gravito-magnetic nature, he introduced Mach's principle—that the inertia of matter is the result of the gravitational interactions between particles—into his program for general relativity. The paper appeared in a journal of forensic medicine because it was intended for a *Festschrift* celebrating the founding of an institute of forensic medicine at the University of Zurich to which his friend Heinrich Zangger had been appointed director.

1913

41. "Thermodynamic Deduction of the Law of Photochemical Equivalence" (Dédution thermodynamique de la loi de l'équivalence photochimique). *Journal de physique* 3 (1913): 277–282. This is a published version of a lecture Einstein gave to the French Physics Society at the end of March, dealing with the topics covered in the supplement to the 1912 paper, "Thermodynamic Proof of the Law of Photochemical Equivalence."
42. "Some Arguments for the Assumption of Molecular Agitation at Absolute Zero" (Einige Argumente für die Annahme einer molekularen Agitation beim absoluten Nullpunkt" (with Otto Stern). *Annalen der Physik* 40 (1913): 551–60. In this paper, Einstein and Stern show that the quantum theory of solids, to give the best agreement with experiments at normal temperatures, seems to demand that at absolute zero a residual energy would remain in the solids, which they term "zero-point energy." They thus introduced this important concept to physics.
43. "Max Planck als Forscher" (Max Planck as Scientist). *Die Naturwissenschaften* 1 (1913): 1077–1079. Einstein wrote of German physicist Planck as an artist as well as a scientist, explaining that his scientific achievements show artistic creativity. He would speak about Planck again in 1918 on Planck's sixtieth birthday, and upon his death in 1948.
44. "On the Present State of the Problem of Gravitation" (Zum gegenwärtigen Stande des Gravitationsproblems). *Physikalische Zeitschrift* 14 (1913): 1249–1262. Einstein gave this lecture at the 85th meeting of the Society of German Natural Scientists and Physicians in Vienna on September 23, 1913. In addition to discussing his own work, he covers Nordström's scalar theory, a serious competitor to Einstein's theory. He concluded that only experience could show which of the two was correct. Further discussion by participants followed the talk.
45. *Outline of a Generalized Theory of Relativity and of a Theory of Gravitation* (Entwurf einer verallgemeinerten Relativitätstheorie und einer Theorie der Gravitation) (with Marcel Grossmann). Leipzig: Teubner, 1913. In this

book, Einstein and Grossmann investigate curved space and curved time as they relate to a theory of gravity. They present virtually all the elements of the general theory of relativity with one striking and crucial omission: their gravitational field equations are not generally covariant. Einstein soon reconciled himself to this lack of general covariance through the hole argument, which tried to establish that generally covariant gravitational field equations would be physically uninteresting. Einstein did not adopt the correct gravitational field equations until late in 1915 in his final formulations of the general theory. In this book, Einstein contributed the part on physics, and Grossmann the part on mathematics.

1914

46. "Physical Foundations of a Theory of Gravitation" (Physikalische Grundlagen einer Gravitationstheorie). Based on a lecture given on September 9, 1913, to the 96th annual meeting of the Swiss Society for Natural Sciences in Frauenfeld. Published the following year in *Naturforschende Gesellschaft in Zürich. Vierteljahrsschrift* 58 (1914): 284–290. Einstein reviews the theoretical aspects of gravitation theory, using more mathematics than in the actual lecture, in which he emphasized the physical content and omitted the mathematical details.
47. "On the Present State of the Problem of Specific Heats" (Zum gegenwärtigen Stande des Problems der spezifischen Wärme). Paper presented at the first Solvay Conference, November 3, 1911. Published in 1914 in Arnold Eucken, ed., *Die Theorie der Strahlung und der Quanten*, 330–352. Halle, Germany: Knapp, 1914. In this report to an international congress, Einstein elaborated in detail his multifaceted ideas involving the theory of quanta.
48. "On the Foundations of the Generalized Theory of Relativity and the Theory of Gravitation" (Prinzipielles zur verallgemeinerten Relativitätstheorie und Gravitationstheorie). *Physikalische Zeitschrift* 15 (1914): 176–180. This detailed exposition of the "hole argument" implies that the metric tensor $g^{\mu\nu}$ cannot be uniquely determined by generally covariant field equations. This argument is important in reconstructing Einstein's early understanding of the relationship between the coordinate description of a spacetime manifold and its physical properties.
49. "On the Relativity Problem" (Zum Relativitäts-Problem). *Scientia* 15 (1914): 337–348. Einstein makes general references to the unsuccessful search for effects of the Earth's motion.
50. "Contributions to Quantum Theory" (Beiträge zur Quantentheorie). *Deutsche Physikalische Gesellschaft. Verhandlungen* 16 (1914): 820–828. Einstein attempts to derive Planck's radiation law and Nernst's third law of thermodynamics in a novel manner, based entirely on thermodynamics. The proofs introduce the quantum hypothesis.
51. "The Formal Foundation of the General Theory of Relativity" (Die formale Grundlage der allgemeinen Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1914): 1030–1085. According to John Norton ("How Einstein Found His Field Equations"), this major review article is intended to convey the full content of the 1913 "Entwurf" theory (no. 45). "The principal novelty lies in the mathematical formulation of the theory. Drawing on earlier work with Grossmann, Einstein formulated his gravitational field equations using a variation principle. Using this richer mathematical structure, Einstein offered a proof purporting to demonstrate that his theory had the maximum covariance compatible with the hole argument; that is, covariance under 'justified' transformations between the 'adapted coordinate systems' he had introduced with Grossmann."
52. "Covariance Properties of the Field Equations of the Theory of Gravitation Based on the Generalized Theory of Relativity" (Kovarianzeigenschaften der Feldgleichungen der auf die verallgemeinerte Relativitätstheorie gegründeten Gravitationstheorie) (with Marcel Grossmann). *Zeitschrift für Mathematik und Physik* 63 (1914): 215–225. To increase the inner

consistency of the theory expounded in nos. 45 and 51, the authors apply an action principle for the derivation of the field equations for the metric tensor $g^{\mu\nu}$ ”.

53. “Inaugural Lecture of Mr. Einstein” (Antrittsrede des Hrn. Einstein). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1914): 732–742. In this speech before the Prussian Academy of Sciences, Einstein thanks the members for welcoming him into an academy where he can devote himself exclusively to research. He also discusses how a theoretician conducts his work, giving relativity theory as an example.
54. “Nordström’s Theory of Gravitation from the Point of View of the Absolute Differential Calculus” (Die Nordströmsche Gravitationstheorie vom Standpunkt des absoluten Differentialkalküls) (with A. D. Fokker). *Annalen der Physik* 44 (1914): 321–328. Einstein and Fokker reformulate the theory of gravity proposed by Gunnar Nordström using tensor calculus. The version of Nordström’s theory presented here is thus the very first covariant metric theory to appear in the scientific literature, before the completed form of general relativity the next year.

1915

55. “Experimental Proof of the Existence of Ampère’s Molecular Currents” (with Wander J. de Haas) (in English). *Koninklijke Akademie van Wetenschappen te Amsterdam. Proceedings* 18 (1915–16). A German version was published earlier in *Deutsche Physikalische Gesellschaft. Verhandlungen* 17 (1915): 152–170. A correction to it was published on p. 203 and a comment on p. 420. Considering that Ampère hypothesized that magnetism is caused by the microscopic circular motions of electric charges, the authors propose a design to test the Dutch physicist H. A. Lorentz’s theory that the rotating particles are electrons. The aim of the experiment is to measure the torque generated by a reversal of the magnetization of an iron cylinder. Einstein wrote three papers with Wander J. de Haas on experimental work they did together on Ampère’s molecular currents known as the Einstein-De Haas effect. He immediately wrote a correction when Lorentz pointed out an error in the original paper.
56. “On the General Theory of Relativity” (Zur allgemeinen Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1915): 778–786. An addendum was added a week later in the same journal. This important paper on general relativity, written after Einstein had abandoned his “hole argument” and was closing in again on generally covariant field equations, begins by recounting Einstein’s three-year search for the correct field equations of gravitation. He concludes that “the magic of this theory will hardly fail to impose itself on anybody who has truly understood it; it represents a genuine triumph of the method of absolute differential calculus founded by Gauss, Riemann, Christoffel, Ricci, and Levi-Civita.”
57. “Explanation of the Perihelion Motion of Mercury from the General Theory of Relativity” (Erklärung der Perihelbewegung des Merkur aus der allgemeinen Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1915): 831–839. Einstein gives an astronomical confirmation of general relativity by using as an example the perihelion advance of Mercury. This result convinced Einstein, and many others, that the new theory was probably correct and could supersede Newton’s long-standing theory of gravity.
58. “The Field Equations of Gravitation” (Die Feldgleichungen der Gravitation). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1915): 844–847. Dropping a previous restriction, Einstein rewrites his field equations of gravitation. In the three papers (nos. 56, 57, and this one), all published in November 1915, Einstein gave expositions of his new theory of gravitation and the mathematical generalization of the theory of relativity. He concluded that while spacetime in the special theory is geometrically flat, in the general theory it is curved and includes gravity as a determinant. The seminal paper, however, was not published until 1916

(no. 62). No. 58, however, solved a long-standing problem in astronomy and was one of the main triumphs of the general theory of relativity. It also contains the first statement of what are now known as the Einstein equations, the governing equations of the gravitational field.

1916

59. "My Opinion on the War" (Meine Meinung über den Krieg). Written in October–November 1915 but not published until the following year in *Das Land Goethes 1914–1916*, with two paragraphs from the manuscript omitted. Stuttgart and Berlin: Deutsche Verlags-Anstalt, 1916. Einstein wrote this statement for a volume of "patriotic commemoration" to be published by the Goethebund of Berlin in which Germans were called on to defend German culture in the midst of war. In it, Einstein declared that war was rooted in the "biologically determined aggressive tendencies of the male." He upheld pacifism and rejected war under any circumstances.
60. "A New Formal Interpretation of Maxwell's Field Equations of Electrodynamics" (Eine neue formale Deutung der Maxwellschen Feldgleichungen der Elektrodynamik). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1916): 184–188. Einstein reformulates Maxwell's equations in the language of tensor calculus and in light of his recent discovery of the field equations of general relativity. Later in the year (see no. 62), he would show how, in the weak-field limit, his own field equations of gravity would bear a close resemblance to this formulation of Maxwell's theory.
61. "Ernst Mach." *Physikalische Zeitschrift* 17 (1916): 101–104. In this long eulogy for Ernst Mach, the natural philosopher who had greatly influenced him, Einstein praises him as an original thinker who has had the greatest influence on the epistemological orientation of natural scientists. His "philosophical studies sprang from his desire to find a point of view from which the various branches of science ... can be seen as an integrated endeavor."
62. "The Foundation of the General Theory of Relativity" (Die Grundlage der allgemeinen Relativitätstheorie). *Annalen der Physik* 49 (1916): 769–822. Published as a book in Leipzig: Barth, 1916. This long and seminal paper is the earliest complete exposition of Einstein's general theory of relativity, giving a comprehensive account of the final version of the theory after publication of his latest revisions in the papers of November 1915. In it, he presents the tools of tensor analysis that allowed him to derive the general field equations for gravity as a property of non-Euclidean space time. For the first time, he systematically uses the term "special theory of relativity," though he had already made reference to it in two papers of 1915 (nos. 56 and 58). In conclusion, he discusses the theory's success in explaining phenomena such as the bending of light rays in a gravitational field, an achievement that helped to establish the superiority of general relativity over classical Newtonian theory and thereby redefined our conception of the universe.
63. "Approximative Integration of the Field Equations of Gravitation" (Näherungsweise Integration der Feldgleichungen der Gravitation). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1916): 688–696. Einstein had to retract this paper's results on gravitational waves in 1918 because of a serious error. The paper nevertheless remains of interest because it introduces an important approximation scheme in general relativity, the linearized approximation. In this scheme, instead of pursuing the obvious comparison between the theory and Newtonian gravity, Einstein explores the analogy between his new field theory of gravity and its other model, Maxwell's field theory of electromagnetism.
64. "Emission and Absorption of Radiation in Quantum Theory" (Strahlungs-Emission und -Absorption nach der Quantentheorie). *Deutsche Physikalische Gesellschaft. Verhandlungen* 19 (1916): 318–323. This work represents a major step forward in quantum theory. Here Einstein proposes to replace

electromagneto-mechanical considerations with quantum-theoretical contemplations on the interaction between matter and radiation.

65. "On the Quantum Theory of Radiation" (Zur Quantentheorie der Strahlung). *Physikalische Gesellschaft Zürich. Mitteilungen* 18 (1916): 47–62. Also published the following year in *Physikalische Zeitschrift* 18 (1917): 121–128. In this paper, Einstein states that one arrives at a theory that is free of contradictions only if the elementary processes are interpreted as completely directed processes. He wrote to his friend Michele Besso on August 24, 1916, that "the derivation is purely quantized and yields Planck's formula. In connection with this, it can be demonstrated convincingly that the elementary processes of emission and absorption are directed processes. One just has to analyze the (Brownian) motion of a molecule (in the sense of that derivation) within a radiation field."
66. "Elementary Theory of Water Waves and of Flight" (Elementare Theorie der Wasserwellen und des Fluges). *Die Naturwissenschaften* 4 (1916): 509–510. Einstein had lectured on this topic, in which he proposes an airfoil design, at a meeting of the German Physical Society. When placed in a moving fluid, a body will experience a net upward force, enabling it to serve as an airfoil. In 1917, a Berlin aircraft firm tested the design, which failed. A few months before his death, Einstein admitted to Paul Ehrhardt, the test pilot, that "I have often been ashamed of my folly of those days."
67. "Hamilton's Principle and the General Theory of Relativity" (Hamiltonsches Prinzip und die allgemeine Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1916): 1111–1116. Inspired by the work of Hilbert and Lorentz, Einstein derives the recently formulated field equations of general relativity from a single variational principle, an approach that came to be seen as characteristic of a well-formulated field theory.

1917

68. *On the Special and the General Theory of Relativity: A Popular Account* (Über die spezielle und die allgemeine Relativitätstheorie [Gemeinverständlich]). Braunschweig, Germany: Vieweg, 1917. [First English edition, trans. Robert W. Lawson: *Relativity: The Special and the General Theory. A Popular Exposition*, came later (London: Methuen, 1920; American edition: Henry Holt, 1920).] This book presents a popular account of relativity theory, both special and general. Finding it difficult to write at this level, Einstein felt he had no choice but to do so if his theories were to be understood. The book was intended "to give an exact insight into the theory of relativity to those readers who, from a general and philosophical point of view, are interested in the theory, but who are not conversant with the mathematical apparatus of theoretical physics." Rather than writing elegantly, he repeated himself frequently "in the interest of clearness." The book was a huge success, with fourteen editions appearing between 1917 and 1922—and it is still available today—with only minor revisions made in subsequent editions. Translations into other languages followed, making relativity theory known throughout the world.
69. "Cosmological Considerations in the General Theory of Relativity" (Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1917): 142–152. Einstein's first paper on cosmology was published in the spring. He added a "cosmological constant" in an attempt to balance the field equations of general relativity. It enabled him to describe a universe that conformed to what he and everyone else assumed: a closed and static sphere that was coextensive with the Milky Way. His chief innovation was to propose a universe with positive overall curvature which closed in on itself so that it was finite in volume but with no boundary. All of modern cosmology can be traced back to this paper, in which Einstein applied general relativity to cosmological questions for the first time. He later rejected the cosmological constant altogether, but it nevertheless refused to die and made several comebacks. Today, it is once

again at the center of cosmology with the discovery of the acceleration of the expansion of the universe. (The incident has often been referred to as the “biggest blunder” of his life, particularly by physicist George Gamow in an article in the September 1956 issue of *Scientific American*. In it, he claimed that Einstein used those words in his presence even though there is no other documented evidence that he felt this way. See atlantic.com, August 9, 2013.)

70. “On the Quantum Theory of Radiation” (Zur Quantentheorie der Strahlung). *Physikalische Zeitschrift* 18 (1917): 121–128. Besides being a penetrating analysis of the properties of photons, this paper also shows that Planck’s law for thermal radiation could be simply deduced from assumptions that conform to the basic ideas of the quantum theory of atomic structure, based on the concept of transition probabilities. Einstein boldly uses this probabilistic approach to characterize the spontaneous emission of radiation by atoms (controversial because it appeared to apply not only to ensembles, but even when an individual atom might suddenly decay). He also discusses how atoms may be stimulated to undergo decay by the presence of radiation of the correct frequency, an insight that would later inspire the development of lasers, which work by stimulated emission of light.
71. “On the Quantum Theorem of Sommerfeld and Epstein” (Zum Quantensatz von Sommerfeld und Epstein). *Deutsche Physikalische Gesellschaft. Verhandlungen* 19 (1917): 82–92. Einstein presents a coordinate invariant form of Epstein’s formal presentation of the Bohr-Sommerfeld quantization rules. This paper was influential in the development of quantum mechanics, as cited by both De Broglie and Schrödinger. Subsequently, it was forgotten for decades until it was revived for its insight into what are now called chaotic systems that do not obey these quantization rules. The difficult subject of quantum chaos is at the forefront of research today, where this semiclassical method of quantization is known as the Einstein-Brillouin-Keller method.
72. “Manifesto to the Europeans” (Aufruf an die Europäer) (October 1914) (with Georg Nicolai, Wilhelm Foerster, and Otto Buek). Not published until 1917 as the introduction to Nicolai’s *Die Biologie des Krieges*. Zurich: Orell Füssli, 1917; English edition: *The Biology of War*, trans. C. A. Grande and J. Grande. New York: Century, 1918. In Einstein’s widely circulated first public statement on a nonscientific topic, he responds to another manifesto in which ninety-three German intellectuals and artists had defended German military actions in Belgium at the beginning of the First World War. This countermanifesto was drafted by pacifist, physician, and professor of medicine and physiology Georg Nicolai, collectively emended and signed by Einstein, Nicolai, and the two others. (See this volume, [Part III](#), Political Contexts, “The First World War—Manifesto to the Europeans.”)
73. “The Nightmare” (Der Angst-Traum). *Berliner Tageblatt*, December 25, 1917. In this short article, Einstein addresses the question of whether the compulsory secondary-school leaving exam should be abolished. Einstein was in favor of discontinuing the exam, maintaining that it does not succeed in testing a pupil’s knowledge and depends too much on short-term rote learning. He felt the exam was useless as well as harmful. See also no. 155. (See this volume, [Part III](#), Education: Einstein’s Views.)

1918

74. “On Gravitational Waves” (Über Gravitationswellen). *Königlich Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1918): 154–167. Correcting errors from his first treatment of the subject (see no. 63), Einstein presents the first concrete and substantially correct theory of gravitational waves. These waves are regarded as one of the most remarkable predictions of general relativity, since they are completely absent from the traditional Newtonian theory. Observational evidence for their existence became available in 1979 from observations of the first binary pulsar, observations that confirmed the most famous result of this

paper, the quadrupole formula, in which Einstein predicted the flux of gravitational wave energy from an emitting system. Only in recent times is it becoming technologically possible to search for such waves as they pass by the Earth. Several detectors designed for the purpose are currently under continuing development.

75. "On the Foundations of the General Theory of Relativity" (Prinzipielles zur allgemeinen Relativitätstheorie). *Annalen der Physik* 55 (1918): 241–244. Here we are given the first new presentation of the foundations of general relativity since the developments of March 1916, when Einstein gave his first systematic exposition.
76. "Motives for Research" (Motive des Forschens). In *Zu Max Plancks sechzigstem Geburtstag* (On Max Planck's Sixtieth Birthday). Karlsruhe: C. F. Müllersche Hofbuchhandlung, 1918. Reprinted in *Ideas and Opinions* (1954). This paper was based on a lecture that Einstein delivered in Berlin as part of a special session of the German Physical Society in honor of German physicist Max Planck's sixtieth birthday. Planck, a professor of theoretical physics at the University of Berlin, is best known for his quantum theory of 1900, which provided the basis for the modern development of atomic physics. Here Einstein uses Planck as a model scientist, whose daily efforts on behalf of science come from the heart and not from any other motivations.
77. "The Law of Energy Conservation in the General Theory of Relativity" (Der Energiesatz in der allgemeinen Relativitätstheorie). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1918): 448–459. Einstein answers criticisms of his conservation law in general relativity and the pseudotensor used to express it. He argues that an integral form of the law is appropriate, and shows that the integral of a closed system's total energy is invariant and conserved and can be measured only far from the source. The pseudotensor played the key role in his analysis of gravitational waves. No. 74, where he uses it to derive the quadrupole formula, stands in testimony to Einstein's successful use of this controversial quantity. No. 63, where his error lay in constructing an incorrect form of the pseudotensor, stands as a harsh warning to the careless use of this noninvariant quantity that is thus different for different observers (or different frames of reference).
78. "Dialogue about Objections to the Theory of Relativity" (Dialog über Einwände gegen die Relativitätstheorie). *Die Naturwissenschaften* 6 (1918): 697–702. This article on the paradoxes of the theory of relativity was written in dialogue form between Einstein and his critics.

1919

79. "Do Gravitational Fields Play an Essential Role in the Structure of the Elementary Particles of Matter?" (Spielen die Gravitationsfelder im Aufbau der materiellen Elementarteilchen eine wesentliche Rolle?). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1919): 349–356. In this published lecture to the Prussian Academy of Sciences, Einstein visualized the relations in spherical space and discussed the field equations in general relativity from the point of view of the cosmological problem and the problem of the constitution of matter. He particularly pursued the notion that the field equations of general relativity might provide an explanation for the "Poincaré stresses" believed at that time to be necessary to stabilize the electron.
80. "Immigration from the East" (Die Zuwanderung aus dem Osten). *Berliner Tageblatt*, December 30, 1919, morning edition, p. 2. In this article, Einstein speaks out against those who claim that Jews from Eastern Europe were responsible for Germany's problems after the war.

1920

81. *Ether and the Theory of Relativity* (Äther und Relativitätstheorie). Berlin: Springer, 1920. Einstein's lecture at the University of Leyden on the

occasion of his appointment as a visiting professor summarizes his current views on the ether. He retrospectively looks at the development of his opinions on the physical properties of space, and acknowledges that though his theory of special relativity banished the luminiferous ether, his theory of general relativity had arguably introduced a new ether, the fabric of spacetime itself, which, though intangible, plays an essential role in that theory.

82. "Propagation of Sound in Partly Dissociated Gases" (Schallausbreitung in teilweise dissoziierten Gasen). *Königlich Preussische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1920): 380–385. This paper on the determination of chemical reaction velocities in partly dissociated gases by using sound propagation may appear to be off the beaten track for Einstein, but he dabbled with problems of fluids (liquids and gases) throughout his life. At the time it was published, the paper did not garner much attention, but molecular acoustics later became a novel investigative tool in physical chemistry.
83. "To the 'General Association for Popular Technical Education'" (newspaper report quoting a statement by Einstein). *Neue Freie Presse*, July 24, 1920, morning edition, p. 8. In this statement, solicited by the association, Einstein stresses the importance of showing to students and the public the practical applications of science and technology to everyday life. He states his belief that a technical education is equal in value to a humanistic one.
84. "My Response. On the Anti-Relativity Company" (Meine Antwort. Über die anti-relativitätstheoretische G.m.b.H.). *Berliner Tageblatt*, August 27, 1920, morning edition, pp. 1–2. In the popular Berlin newspaper, Einstein, after having resisted public responses on earlier provocations, repudiates the attacks that had been leveled against him and relativity theory since 1918. The final straw had been two lectures that were delivered on August 24 in the Berlin Philharmonic Hall. On this occasion, his accusers put aside any scientific criticisms and charged him with plagiarism, with being hungry for publicity, manipulating the press, conducting un-German science, and so on.
85. "Ein Bekenntnisbrief Einsteins" (A Letter of Confession by Einstein). *Israelitisches Wochenblatt für die Schweiz*, September 24, 1920, p. 10. The letter, intended as a private communication, was written a half-year earlier and made its way mysteriously into the press. Einstein refuses an invitation to address the Central Association of German Citizens of the Jewish Faith, mocking its elitism and stressing the need for solidarity with East European Jews. (See also this volume, [Part III](#), Jewish Identity and Ties, "The Cultural Zionist Ideal.")
86. *Relativity: The Special and the General Theory*. First English edition, 1920. See no. 68.

1921

87. "The Common Element in Artistic and Scientific Experience" (Das Gemeinsame am künstlerischen und wissenschaftlichen Erleben). *Menschen. Zeitschrift neuer Kunst* 4 (1921): 19. In this short statement, Einstein emphasizes that art and science have common elements in that both give expression to creativity: in science through logic, and in art through form. Both help one escape from the merely personal.
88. *Geometry and Experience* (Geometrie und Erfahrung). Berlin: Springer, 1921 (an expanded version of a lecture, held at the Prussian Academy of Sciences on January 27, 1921). (English version published in *Sidelights in Relativity*. London, Methuen, 1922.) Lecturing to a session of the Prussian Academy of Sciences commemorating Frederick the Great, Einstein discusses the special esteem mathematics receives. He sums up his views on the geometrization of physics and relativity and the relation of mathematics to the external world. He asks if human reasoning, even without direct experience, can lead to an understanding of the properties of real things merely through thought. Considering the puzzling question of why mathematics should be so well adapted to describing the external world, he concluded: "As far as

the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.”

89. “A Brief Outline of the Development of the Theory of Relativity.” *Nature* 106 (1920–21): 782–784. Trans. from the German manuscript by Robert Lawson. In a special issue of *Nature* devoted to relativity theory, Einstein and other European contributors write about the contemporary results and problems of the theory in the hope of restoring international scientific cooperation after the war. Einstein describes the sequence of ideas that led to his theory and concludes with prescient remarks on the questions that remain.
90. “How I Became a Zionist” (Wie ich Zionist wurde). *Jüdische Rundschau*, June 21, 1921, pp. 351–352. In an interview by the editor of the Jewish magazine, Einstein maintains that intellectuals are the propagators of anti-Semitism, that elites use anti-Semitic sentiments for political gain, but that hatred comes from those who are “primitive and uneducated” about those who are different from them. He also takes the opportunity to reiterate his indifference to Judaism as a religion.
91. “Een Interview met Prof. Albert Einstein” (An Interview with Prof. Albert Einstein). *Nieuwe Rotterdamsche Courant*, July 4, 1921. A translation of the Dutch original is provided in *CPAE*, Vol. 7, appendix D, pp. 623–625. The interview, conducted in Berlin by a Dutch correspondent after Einstein’s return from his fund-raising trip to America, provoked outrage in the United States. Perhaps most offensive was his claim that American men were “toy dogs for their wives, who spend the money in the most excessive fashion.” Realizing that he had gone too far, Einstein claimed subsequently that he had been misquoted.
92. “On a Jewish Palestine” (based on an address given by Einstein in Berlin on June 27, 1921). *Jüdische Rundschau*, July 1, 1921, p. 371. Einstein emphasizes the importance of Palestine as a symbol of Jewish cultural unity over its importance as a Jewish settlement; cultural unity was the basis of his support of Zionism at this time.
93. “On the Founding of the Hebrew University of Jerusalem” (Zur Errichtung der hebräischen Universität in Jerusalem). *Jüdische Pressezentrale Zürich*, August 26, 1921, p. 1. In this article, Einstein supports the establishment of a university in Jerusalem and advocates an emphasis on the sciences and health professions. He feels that it is necessary for a Jewish homeland to have a university both for its own citizens as well as to give those Jews who were barred from attending other universities a place to study, teach, and conduct research. He also hopes that when such an institution gains a distinguished international reputation, Jews will no longer be inclined to hide their group identity as Jews wherever they might work.
94. “The Plight of German Science: A Danger for the Nation” (Die Not der deutschen Wissenschaft. Eine Gefahr für die Nation). *Neue Freie Presse*, December 25, 1921, morning edition, p. 1. See also no. 102. This statement was solicited by the editor of the paper to promote scientific interests between Germany and Austria. Fearing the collapse of scientific research due to the dismal economic conditions in Germany, Einstein appeals to wealthy private donors to supplement the government’s appropriation to a privately endowed emergency fund. He emphasizes that “the insights and methods created by science usually serve practical purposes only in an indirect way and often only for future generations.”

1922

95. “On an Experiment concerning the Elementary Process of Light Emission” (Über ein den Elementarprozeß der Lichtemission betreffendes Experiment). *Königlich Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1921, but published January 5, 1922): 882–883. Einstein asserts his belief that light quanta are real by proposing an experiment that shows the breakdown of wave optics directly through a nonstatistical phenomenon rather than the statistical evidence for the quantization of light produced so far.

96. "Impact of Science on the Development of Pacifism." German contribution to Kurt Lenz and Walter Fabian, eds., *Die Friedensbewegung* (The Peace Movement), 78–79. Berlin: Schwetschke, 1922. Because technical inventions that arise from science have international consequences, including military applications, men must create organizations dedicated to preventing wars whenever there is a possibility that such products might be used violently.
97. *Four Lectures on the Theory of Relativity, Held at Princeton University in May 1921* (Vier Vorlesungen über Relativitätstheorie gehalten im Mai 1921 an der Universität Princeton). Braunschweig, Germany: Vieweg, 1922. (English version published by Methuen in London as *The Meaning of Relativity*, trans. Edwin P. Adams. See also 5th ed., pbk., Princeton Science Library. Princeton, NJ: Princeton University Press, 1988.) In 1921, during Einstein's first trip to the United States, he gave a series of five lectures on relativity theory at Princeton University. This book is based on these lectures, though two of the lectures were combined into one for the book. It is still in print, with several revisions and additions made in later editions.
98. "On the Theory of Light Propagation in Dispersive Media" (Zur Theorie der Lichtfortpflanzung in dispergierenden Medien). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1922): 18–22. In this paper submitted to the Prussian Academy of Sciences, Einstein introduces a calculation on the topic and explains why an earlier proposed experiment of his had not been well considered because it could not predict a good choice between two theoretical alternatives.
99. "Quantum Theoretical Comments on the Experiment of Stern and Gerlach" (Quantentheoretische Bemerkungen zum Experiment von Stern und Gerlach) (with Paul Ehrenfest). *Zeitschrift für Physik* 11 (1922): 31–34. The two physicists show that the Stern-Gerlach effect, discovered in 1922, has to overcome insurmountable difficulties if it is to show the behavior of atoms in a magnetic field. It poses a problem that cannot be solved using contemporary quantum theory. The authors anticipated what would later become the quantum measurement problem.
100. "On the Present Crisis of Theoretical Physics" (Über die gegenwärtige Krise der theoretischen Physik). *Kaizō* 4 (December 1922), no. 12: 1–8. After reviewing how the scientific system of concepts used in theoretical physics developed and grew, Einstein writes that the foundations of physics will demand fundamental changes in order to continue advancing the field.
101. "How I Created the Theory of Relativity" (Wie ich die Relativitätstheorie entdeckte). Lecture at University of Kyoto, Japan, December 14, 1922. (Notes taken by Yun Ishiwara and translated into English by Y. A. Ono in *Physics Today*, August 1932, p. 45.) In this informal lecture delivered during his trip to Japan, Einstein reflects on his path to relativity theory. Japanese physicist Yun Ishiwara kept notes of the lecture and published them in 1923 in Kyoto, where they were reprinted in 1971. The 1932 translation by Ono in *Physics Today* refreshed Einstein's memory later in life about this important part of his scientific journey.
102. "The Peril to German Civilisation." *New Leader* 1 (1922): 11. Einstein answers questions about the German economy, posed by the editor of the bimonthly opinion magazine. He is concerned mainly about the reduction of salaries for teachers and other intellectual workers (or "brain workers," as he refers to them) due to German war debts. He fears that the middle class is losing ground and may fail to reach its potential.

1923

103. "Musings on My Impressions in Japan." *Kaizō* 5 (1923): 338–343. In this article, in which Einstein pauses to reflect on his trip to Japan, he clearly shows his enchantment with the country and the Japanese people. He observes that the land is "shrouded in a veil of mystery," that everything that is native to Japan is "delicate and joyful" and connected to nature. He later wrote his son Hans Albert that the Japanese were "better than all the people I've met up to now: quiet, modest, intelligent."

104. "On the General Theory of Relativity" (Zur allgemeinen Relativitätstheorie). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1923): 32–38 (note appended on 76–77). Written in January 1923 aboard the *Haruna Maru* on his return trip from Japan to Berlin, in this document Einstein searches for a unified theory of gravitation and electromagnetism, which would dominate his scientific thinking until his death.
105. "My Impressions of Palestine." *New Palestine* 4 (1923): 341. Einstein recounts the experiences and feelings he encountered during his visit to the future Jewish state. He was not yet concerned about an "Arab question," declaring that Jews and Arabs appeared to live in harmony, and that the major problems were those of sanitation, malaria, and debt. By the end of the decade, after major anti-Jewish disturbances, he became more concerned about the Arabs and their grievances.
106. "Fundamental Ideas and Problems of the Theory of Relativity" (Grundgedanken und Probleme der Relativitätstheorie). In *Nobelstiftelsen: Les prix Nobel en 1921–1922*. Stockholm: Imprimerie Royale, 1923. This paper presents Einstein's Nobel Lecture delivered in Gothenburg, Sweden, on July 11, 1923. Because he did not deliver the lecture at the time of the award, it did not discuss the major prize topic—the discovery of the photoelectric effect—and surveyed relativity theory instead.
107. "Does Field Theory Offer Possibilities for Solving the Quanta Problem?" (Bietet die Feldtheorie Möglichkeiten für die Lösung des Quantenproblems?). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1923): 359–364. Einstein writes that despite great successes in quantum theory for a quarter of a century, there is still no logical foundation for the theory, and one must question whether the remaining difficulties could be overcome by the consistent development of earlier theories.

1924

108. "The Compton Experiment" (Das Komptonsche Experiment). *Berliner Tageblatt*, April 20, 1924, suppl., p. 1. Einstein discusses Arthur Compton's discovery of 1922 that an X-ray's wavelength is increased when incident radiation is scattered by free electrons, implying that the scattered quanta have less energy than the quanta of the original beam. This effect, now known as the Compton effect, clearly illustrates the particle concept of electromagnetic radiation. Compton received the Nobel Prize in physics in 1927 for this discovery.
109. "On the One-Hundredth Anniversary of Lord Kelvin's Birth" (Zum hundertjährigen Gedenktage von Lord Kelvins Geburt). *Naturwissenschaften* 12 (1924): 261–267. The work of Lord Kelvin (William Thomson) was based in its entirety on the fundamentals of Newtonian mechanics. Einstein recounts its influence on other researchers, such as James Clerk Maxwell. Instead of giving an overview of Thomson's life, he gives a few examples of the scientist's work that he finds particularly appealing.
110. "Quantum Theory of the Monatomic Ideal Gas" (Quantentheorie des einatomigen idealen Gases). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1924): 261–267. Other treatises on the subject were published in the same journal (1925): 3–14 and 18–25. Einstein responds to the work of the Indian physicist Satyendra Bose, whose paper he himself had submitted to the *Zeitschrift für Physik*, at Bose's request, to ensure its publication. He envisions a penetrating analogy between the properties of thermal radiation (the subject of Bose's paper, which re-derives the Planck law for thermal radiation from more elementary statistical considerations) and gases of the "degenerate state."

1925

111. "Mission of Our University." *New Palestine* 8 (1925): 294. As a new member of the governing board of the Hebrew University of Jerusalem, Einstein outlines the goals of the newly established university for which he had

helped raise funds.

112. "Unified Field Theory of Gravitation and Electricity" (Einheitliche Feldtheorie von Gravitation und Elektrizität). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1925): 414–419. This was Einstein's first paper that used the term "unified field theory" in the title. It was also the beginning of his own long series of papers on this subject, in the sense that his earlier papers on the topic had largely been investigations of the proposals of others, including Hermann Weyl, Theodor Kaluza, and Arthur Stanley Eddington. Here he proposes to base his unified field on the affine connection as well as the metric, with both entities permitted to be asymmetric (in general relativity the fundamental quantity is the metric, which must be symmetric). He saw the asymmetric part of the resulting field as being the representative of electromagnetism, but had only limited success in demonstrating his point. He eventually returned to the theory in the last decade of his life.
113. "The Electron and General Relativity" (Elektron und Allgemeine Relativitätstheorie). *Physica* 5 (1925): 330–334. In parallel with the unified field theory program begun in no. 112, this paper is an early example of a series of papers—which continued until his death—in which he explored, within the confines of general relativity, possible pathways in the direction of a unified field theory. Here he discusses whether it is possible to explain why electrons and protons have equal charge but unequal masses. He notes that a more natural solution to the field equations would be particles of opposite sign and equal mass, thus anticipating (but for unrelated reasons) the later prediction and discovery of the positron.
114. "Quantum Theory of the Ideal Gas" (Quantentheorie des idealen Gases). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* n.v. (1925): 18–25. Having observed that the ideas of the Indian physicist Satyendra Bose are based on the idea of a photon gas, that is, they are based on an analogy between the statistical behavior of photons and those of atoms in an ideal gas, Einstein turns the analogy around. He applies Bose's insight about photons (that they are indistinguishable particles) to the case of monatomic ideal gases. In doing so, he is led to the famous prediction of the Bose-Einstein condensation effect and one of the earliest statements of wave properties in particles of matter.

1926

115. "On the Cause of the Formation of Meanders in the Courses of Rivers ..." (Über die Ursache der Mäanderbildung der Flussläufe und des sogenannten Baerschen Gesetzes). *Naturwissenschaften* 14 (1926): 223–334. English translation in *Ideas and Opinions* (1954). Read first before the Prussian Academy of Sciences on January 7, this paper discusses why the erosion of rivers tends to take place on the right bank in the Northern Hemisphere and on the left in the Southern. Having found no one who was thoroughly familiar with the causal relations involved, Einstein decided to tackle the problem himself. He explains that Earth's rotation produces the Coriolis force (operating with a different handedness in the two hemispheres of the world), which is reduced toward the bottom of a river and gives rise to a circular movement in the riverbed. A turbulent distribution of velocities in the bed is developed and maintained and causes erosion. See Illy, *The Practical Einstein*, pp. 10–14, for a discussion of research on meandering conducted before and after Einstein's short paper.
116. "Interference Characteristics of Light Emitted by Canal Rays" (Über die Interferenzeigenschaften des durch Kanalstrahlen emittierten Lichtes). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1926): 334–340. This article appeared in conjunction with an experimental report by Emil Rupp based on the experimental design described here by Einstein. The status of Rupp's experiments based on Einstein's ideas was later cast into doubt when, in 1935, Rupp was forced to retract five of his recent papers after colleagues showed that Rupp did not even possess the apparatus to have carried out the experiments reported in them. It is now

generally believed that all of Rupp's experiments, including those reported to Einstein in an extensive correspondence, were fraudulent. Einstein never visited Rupp's laboratory, as he would normally have done, to observe the experiments, because he was by then totally estranged from Rupp's supervisor, Philipp Lenard.

117. "On Kaluza's Theory on the Connection between Gravitation and Electricity" (Zu Kaluzas Theorie des Zusammenhanges von Gravitation und Elektrizität). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1927): 23–35. Kaluza attempted to unify Einstein's theory of gravity with Maxwell's theory of light by mixing them in a fifth dimension. In 1926, the theory received renewed attention when the mathematician Oskar Klein described how the apparently spurious fifth dimension could be real but unobservable because it was curled up upon itself ("compactified") so that motion in that direction was insensible to us. The theory in this form is usually referred to as the Kaluza-Klein theory.
118. "Newton's Mechanics and Its Influence on the Shaping of Theoretical Physics" (Newtons Mechanik und ihr Einfluß auf die Gestaltung der theoretischen Physik). *Naturwissenschaften* 15 (1927): 273–276. English translation in *Ideas and Opinions* (1954). Writing on the occasion of the two-hundredth anniversary of Newton's death, Einstein traces the historical development of physics, from the Greeks to Galileo to Newton and the present time, especially emphasizing Newton's contributions.
119. "Isaac Newton." Letter to the Royal Society on the 200th anniversary of Newton's death. *Nature* 119 (1927): 467. In this letter, Einstein praises the British for their traditions and for providing an atmosphere that allows the human soul "to soar." Everything that has happened in theoretical physics since Newton's time developed from his ideas, and only in quantum theory has Newton's differential method been inadequate.
120. "General Theory of Relativity and the Laws of Motion" (Allgemeine Relativitätstheorie und Bewegungsgesetze). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1927): 235–245. Einstein attacks the problem of deducing the law of motion from the field equations. He repeatedly returned to this problem in his later work.

1928

121. "Riemannian Geometry with Preservation of the Concept of Distant Parallelism" (Riemanngeometrie mit Aufrechterhaltung des Begriffes des Fern-Parallelismus). *Preußische Akademie der Wissenschaften* (Berlin), *Sitzungsberichte* (1928): 217–221. *See next paper.*
122. "New Possibilities of a Unified Field Theory of Gravitation and Electricity" (Neue Möglichkeiten für eine einheitliche Feldtheorie von Gravitation und Elektrizität). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1928): 224–227. Nos. 121 and 122 discuss Einstein's concept of a unified field theory based on what he referred to as distant parallelism, an idea that came to Einstein during a period of bed rest due to ill health. The mathematical formalism for this theory had, unknown to Einstein, been previously developed by the mathematician Elie Cartan and is today known as Einstein-Cartan theory or "torsion" theory. The "torsion" element of the theory, which mathematically describes an antisymmetric component of the affine connection (or distant parallelism), is considered interesting because of the possibility that it might provide an explanation of the intrinsic spin of elementary particles.
123. "H. A. Lorentz." *Mathematisch-naturwissenschaftliche Blätter* 22 (1928): 24–25. Reprinted as "Address at the Grave of H. A. Lorentz" in *Ideas and Opinions* (1954), 73. In this eulogy at the grave of the Dutch theoretical physicist whom Einstein admired and loved, Einstein calls him the "greatest and noblest man of our time."

1929

124. "On the Unified Field Theory" (Zur einheitlichen Feldtheorie). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1929): 2–7. This exposition of Einstein's theory on unitary field laws for gravitation and electromagnetism (unified field theory, or UFT) focuses on his efforts to find a set of field equations for the distant parallelism approach introduced in nos. 121 and 122. The publication of this paper was immediate news. Ongoing gossip in the mass media had claimed that Einstein had solved the riddle of the universe, and this publication was highly anticipated. The first printing sold out immediately, and the publisher ordered more printings. Einstein could not understand the commotion, even though he had faith in his theory. Critics found fault with it, however, and after a few more attempts at corrections over the following couple of years, Einstein abandoned the distant parallelism approach and returned to a new variant of the Kaluza-Klein theory influenced by his experiences with the current method.

1930

125. "About Kepler" (Über Kepler). *Frankfurter Zeitung*, November 9, 1930. English translation in *Ideas and Opinions* (1954). Writing on the occasion of the three-hundredth anniversary of Johannes Kepler's death, Einstein recounts the difficulties Kepler must have faced while working on planetary motion, and he praises the ingenious methods Kepler used. He concludes that "knowledge cannot spring from experience alone but from the comparison of the inventions of the intellect with observed fact."
126. "Religion and Science." *New York Times*, November 9, 1930. Reprinted in *Ideas and Opinions* (1954), 36–40. Einstein wrote this article expressly for the *New York Times Magazine*. In this somewhat provocative piece, he professes his belief in a "cosmic religion," which to him is a higher level of religion than organized religion. He declares that it is a "miraculous order that manifests itself in all of nature as well as in the world of ideas," and it is devoid of a personal God who rewards and punishes people based on their behavior. He concludes that there is no conflict between science and religion, that indeed cosmic religiosity is necessary for scientific research. (See also this volume, [Part III](#), Religion.)
127. "Science and God: A Dialogue." *Forum and Century* 83 (1930): 373–379. This article is based on a conversation with J. Murphy and J.W.N. Sullivan, touching on the relationship of science to other aspects of life, the question of Jewish racial characteristics, and other topics of interest to Einstein. Sullivan was a mathematician and science popularizer who had undertaken a "tour of great men," interviewing as many eminent scientists as he could find for an upcoming book. James Murphy was an Irish writer, lecturer, and conversationalist.
128. "What I Believe." *Forum and Century* 84 (1930): 193–194. Reprinted as "The World as I See It" in *Ideas and Opinions* (1954), 8–11. Here Einstein puts forth his personal beliefs and philosophy. This piece contains his well-known quotations, "I have never looked upon ease and happiness as ends in themselves—such an ethical basis I call the ideal of a pigsty.... The ideals which have guided my way ... have been Kindness, Beauty, and Truth," and "The most beautiful experience we can have is the mysterious." See also frontmatter of this volume.

1931

129. "Science and Happiness." Speech at California Institute of Technology. Reprinted in *New York Times*, February 22, 1931, sec. 9, 2:1. Also published in *Science*, n.s., 73, no. 1893 (April 10, 1931): 375–381. Einstein rhetorically asks why science has brought so little happiness, and answers: we have not yet learned to make sensible use of it. Scientists must not forget that concern for people's happiness is paramount in all technical endeavors.

130. "Militant Pacifism." *World Tomorrow* 14 (1931): 9. Reprinted in *Ideas and Opinions* (1954) as "Active Pacifism." Einstein made these remarks in response to a peace demonstration in Flemish Belgium, calling for disarmament and hoping that future generations "will look back on war as an incomprehensible aberration of their forefathers."
131. "The Nature of Reality." *Modern Review* (Calcutta) 49 (1931): 42–43. In this conversation, Einstein and Indian musician and poet Rabindranath Tagore discuss the nonmaterial world. This first conversation between the two Nobel laureates took place on July 14, 1930, in Einstein's summer home in Caputh, near Berlin. They discuss humankind's place in the world, and the nature of truth, reality, religion, and beauty.
132. "Tagore Talks with Einstein." *Asia* 31 (1931): 138–142. This second conversation between Einstein and Tagore took place on August 19 in the home of mutual friends, the Mendels, in Berlin. They discuss freedom, determinism, psychology, and philosophical issues but focus on the differences between Eastern and Western music.
133. "The 1932 Disarmament Conference." *Nation* 133 (1931): 300. Reprinted in *Ideas and Opinions* (1954). After declaring that the state should be the servant of man and not vice versa, Einstein discusses the need for international disarmament, abolishment of compulsory military service, and changes in educational systems that hand down military traditions. He decries nationalism as unhealthy because it leads to aggression and war, and calls for the protection of conscientious objectors worldwide. He optimistically believes that dutiful national leaders "do, in the main, honestly desire to abolish war."
134. "On the Cosmological Problem of the General Theory of Relativity" (Zum kosmologischen Problem der allgemeinen Relativitätstheorie). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1931): 235–237. In this paper, Einstein accepts the nonstatic character of the universe and rejects the cosmological constant as unnecessary and as compromising the simplicity of his field equations. *See also* the discussion under no. 69. He wrote this paper in response to the discovery of the expansion of the universe by Edwin Hubble. We now know that Einstein's initial response to this discovery was to begin a paper in which he tried to replace his static universe with a stationary one that is similar to the steady-state universe of the postwar period. In the latter model, the universe did expand (in the sense that individual galaxies will continue to become more distant from one another) but would never change its appearance because new matter created in the space between galaxies would lead to the creation of new galaxies, preserving the density of galaxies in spite of the expansion. He abandoned this approach, however, and accepted that the expansion was not only real, but was changing the universe with time.
135. "Unified Theory of Gravitation and Electricity" (Einheitliche Theorie von Gravitation und Elektrizität), part 1 (with Walther Mayer). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1931): 541–557. *See* no. 138 for part 2. In this paper, Einstein once again changes tack in his search for a unified field theory, returning to the five-dimensional approach of the Kaluza-Klein theory but marrying it to an aspect of his work on distant parallelism. In those papers (*see* nos. 121 and 122), he had introduced a tetrad of vectors at each point in space whose properties were central to the theory. He now adds a vector to the tetrad, making five vectors instead of four.

1932

136. "To American Negroes." *Crisis* 39 (1932): 45. Writing for the NAACP's official journal, Einstein criticizes racism after he witnessed rampant racial prejudice during his visit to the United States in the winter of 1931–1932.
137. "Is There a Jewish View of Life?" *Opinion* 2 (September 26, 1932): 7. Reprinted in *Ideas and Opinions* (1954). In answer to this question, Einstein writes that in his opinion there is no specific Jewish point of view. He believes, however, that the Jewish tradition has a reverence for life and a

positive attitude toward it, and contains “a sort of intoxicated joy and amazement at the beauty and grandeur of this world.”

138. “Unified Theory of Gravitation and Electricity” (Einheitliche Theorie von Gravitation und Elektrizität), part 2 (with Walther Mayer). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1932): 130–137. See no. 135 for part 1. Although this new version of the Kaluza-Klein theory had some formal success in terms of one of the goals of Einstein’s UFT program—reproducing the field equations of gravitation and electricity—it failed in terms of his other two goals. It did not seem to permit solutions to its equations that would correspond to (and provide some explanation for the existence of) observed elementary particles, such as the electron and the proton, nor did it offer any insights into the quantum problem. After attempting to address these two issues in this paper, Einstein once again drops this approach and turns to a new one.
139. “Semivectors and Spinors” (Semi-Vektoren und Spinoren) (with Walther Mayer). *Preußische Akademie der Wissenschaften* (Berlin). *Sitzungsberichte* (1932): 522–550. In this paper, Einstein and his assistant Mayer address the introduction into physics, by Paul Dirac and others, of the concept of the spinor. (The term was coined by Einstein’s friend Paul Ehrenfest, who drew Einstein’s attention to this problem.) Einstein tries to show that constructs of his own invention, called semivectors, would do the work of spinors in what he felt was a mathematically more natural way.
140. “On the Relation between the Expansion and the Mean Density of the Universe” (with Willem de Sitter). *Proceedings of the National Academy of Sciences* (USA) 18 (1932): 213–214. Einstein and de Sitter present a revised cosmological model that solves the Friedmann equations and takes account of Edwin Hubble’s proof of the expansion of the universe. They attempt to incorporate newly available estimates of the mean density and rate of expansion of the system of galaxies, and show that they are consistent with the hypothesis that the universe is geometrically flat. With these assumptions, they find that the cosmological constant is no longer necessary. Einstein left it to others to pursue the implications of this type of cosmology, which would lead to the Big Bang theory.
141. “Introduction and Address to Students of UCLA,” February 1932. In *Builders of the Universe*. Los Angeles: U.S. Library Association, 1932. In this little-known text, presented in both English and German, Einstein discusses the source of his own creative scientific work. The subject is science as a coordination of observed facts, as seen, for example, in the progression from the special theory of relativity to the unified field theory.

1933

142. *Why War?* Trans. Stuart Gilbert. Paris: International Institute of Intellectual Cooperation, League of Nations, 1933. This short pamphlet consists of an exchange of letters between Einstein and Sigmund Freud on the proclivity of humankind to make war, and what can be done to counter it. (See also this volume, [Part III](#), Political Contexts, “The First World War—‘Why War?’”)
143. “Letter to the Prussian Academy of Sciences.” *Science*, new ser. 77 (1933): 444. In this letter of April 5, 1933, Einstein states his reasons for resigning from the Prussian Academy of Sciences (he had resigned in a letter of March 28): he does not wish to live “in a state in which individuals are not granted equal rights before the law as well as freedom of speech and teaching.” He expressed the opinion that the academy had slandered him by accusing him in America and France of “atrocities-mongering” against Germany.
144. “Victim of Misunderstanding.” *The Times* (London), September 16, 1933, p. 12. In this letter, Einstein explains his position on communism. He admits that he has been negligent in permitting Communist-front organizations to use his name and writes that he “would now like to state that I have never favoured Communism and do not favour it now.... Any Power must be the enemy of mankind which enslaves the individual by terror or force,

whether it arises under a Fascist or Communist flag.”

145. “Civilization and Science.” Speech presented at Royal Albert Hall, London, October 4, 1933. Published as “Europe’s Danger, Europe’s Hope” in 1934 by Friends of Europe Publications, no. 4. The meeting was organized by the Refugee Assistance Fund. Einstein spoke on the interrelationship between personal freedom and collective security and concluded that “only through peril and upheaval can nations be brought to further development.”
146. “On the Method of Theoretical Physics.” Herbert Spencer Lecture at Oxford University, June 10, 1933. Oxford: Clarendon, 1933. Reprinted in *Ideas and Opinions* (1954). In this lecture series in honor of philosopher Herbert Spencer, Einstein speaks about the development of the theoretical system, “something ineffable about the real, something occasionally described as mysterious and awe-inspiring,” and the function of pure reason in science. He maintains that pure thought can grasp reality, using mathematical concepts to justify his confidence.
147. “The Two Percent Speech,” in Lief, ed., *The Fight Against War*, pp. 34–37. The speech was delivered three years earlier, at a time when Einstein still hoped that “uncompromising war resistance” by individuals might prevail against the military juggernaut. Hitler’s seizure of power at the beginning of 1933 put an end to this illusion. (See also this volume, [Part III](#), Political Philosophy, “Pacifism.”)
148. “Notes on the Origin of the General Theory of Relativity.” George A. Gibson Foundation Lecture at Glasgow University, June 20, 1933. Glasgow University Publications, no. 20. Glasgow: Jackson, 1933. Reprinted in *Ideas and Opinions* (1954) as “Notes on the Origin of the General Theory of Relativity.” The sponsors of the lecture asked Einstein to speak about the history of his own scientific work. He agreed to the invitation because “it is easier to throw light on one’s own work than on some one else’s,” and one should not neglect to do so out of modesty. He discusses the work of others who had influenced him and which eventually led to his discoveries, and outlines the obstacles he had to overcome in his own thinking.

1934

149. *The World as I See It* (Mein Weltbild). New York: Covici-Friede, 1934. This book is a collection of excerpts and essays on a variety of topics, the first of several future editions. Later editions were abridged and do not contain some of the material in this original version. Among other essays, it includes Einstein’s lectures at King’s College in London and at Columbia University in New York, both given in 1921, and a number of writings on science, Judaism, and politics. Many of these essays and lectures are reprinted in *Ideas and Opinions* (1954).
150. “Education and World Peace.” *Progressive Education* 11 (1934): 440. In this message, read at a New York conference of the Progressive Education Association on November 23, 1934, Einstein says that the United States is in the fortunate position of teaching pacifism in the schools because, due to “no serious danger” of a foreign invasion, it is unnecessary to inculcate a military spirit in pupils. He calls for international rather than national military means of defense and a strengthening of international solidarity.

1935

151. “Peace Must Be Waged.” Interview by R. M. Bartlett. *Survey Graphic* 24 (1935): 384. Einstein offers his view on war and peace in this interview, dealing mainly with Germany’s nationalism since the First World War. He advocates the following: every country should surrender a portion of its sovereignty through international cooperation; populations need to think in international terms; and, to avoid wholesale destruction, nations must sacrifice aggression. He also states his belief that humans can abolish war through education.
152. “Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?” (with B. Podolsky and N. Rosen). *Physical Review*, ser. 2, 47

(1935): 777–780. Here the authors bring to public attention Einstein’s critical attitude toward quantum theory. They elegantly expose the consequences of the quantum-mechanical formalism regarding the representation of a state of a system that consists of two parts that have been in interaction for a limited time interval. If the two particles are in what is now called an “entangled” quantum state, then a measurement of one will instantaneously result in a change in the quantum state of the other, in apparent violation of the relativistic prohibition against information traveling faster than the speed of light (what is sometimes referred to as “spooky action-at-a-distance”). According to the authors’ criteria, they conclude that quantum mechanics does not provide a complete description of physical reality, allowing Einstein and others to adhere to the classical framework or to continue to search for some neoclassical theory that could account for quantum phenomena (such as hidden-variable theories). This paper created contention among physicists and was the basis for many philosophical discussions. It raises issues that later became a major focus for research in the theory of quantum decoherence and lie at the heart of modern quantum computing technology. Although the article is said to have been written by Podolsky (after intense discussions with Einstein), it nevertheless articulates one of Einstein’s core beliefs about quantum mechanics: that its inability to disentangle the future behavior of particles in certain states meant that it gave, as he put it, an incomplete description of the world.

153. “Elementary Derivation of the Equivalence of Mass and Energy.” J. W. Gibbs Lecture of the American Mathematical Society delivered at Carnegie Tech, now Carnegie-Mellon University, in Pittsburgh, December 28, 1934. *Bulletin of the American Mathematical Society* 41 (1935): 223–230. In this highly technical lecture to mathematicians and physicists, Einstein establishes, among other things, the definition of relativistic momentum and relativistic energy without using electromagnetic theory.
154. “The Particle Problem in the General Theory of Relativity” (with Nathan Rosen). *Physical Review*, ser. 2, 48 (1935): 73–77. This paper explores possible representations of elementary particles within the general theory of relativity and thus forms a part of Einstein’s unified field theory program. It is notable for the introduction of the Einstein-Rosen bridge, now called a wormhole, which is a geometrical construction that connects two otherwise distant points in spacetime. Although intended by Einstein and Rosen as a particle model, it has become well known in recent times for its possible role as a rapid means of transport from one place to another, or even as a possible means of constructing time machines (known as “closed timelike curves” in the jargon of the field).

1936

155. “Some Thoughts concerning Education.” Trans. Linda Arronet. *School and Society* 44 (1936): 589–592. Reprinted in *Ideas and Opinions* (1954) as “On Education.” See also no. 73. (See this volume, [Part III](#), Education: Einstein’s Views.) In this speech, given at a State University of New York at Albany convocation to celebrate the tercentenary of higher education in America, Einstein maintains that the aim of education must be to train independently thinking individuals. Their highest goal in life should be to serve their communities. Schools should not educate by fear, force, and arbitrary authority—all of which he had detested in the German educational system of his youth.
156. “Physics and Reality.” *Journal of the Franklin Institute* 221, no. 3 (March 1936): 313–347. Reprinted in *Ideas and Opinions* (1954). Einstein, who was awarded the Franklin Medal in 1935, argues that the quantum-mechanical description can be considered only as a way to account for the average behavior of a large number of atomic systems. He expresses his belief that it should give exhaustive descriptions of individual phenomena: “To believe this [that individual elementary particles can be governed only by statistical laws, rather than deterministically] is logically possible without

contradiction, but it is so very contrary to my scientific instinct that I cannot forgo the search for a more complete conception.”

157. “Two-Body Problem in General Relativity Theory” (with Nathan Rosen). *Physical Review* (ser. 2), 49: 404–405. This letter was written in reply to an article by Ludwik Silberstein, a prominent opponent of relativity within the physics community. Unlike many anti-relativists, Silberstein understood the theory and knew Einstein personally. He seized on Einstein and Rosen’s previous paper (no. 154) to argue that the two ends of the Einstein-Rosen bridge were two separate particles whose failure to move closer to each other represented a violation of what we know about gravity. In this reply, Einstein and Rosen observe that the system contains singularities so that it cannot be taken as a dynamical physical system for Silberstein’s purposes.
158. “Lens-like Action of a Star by Deviation of Light in the Gravitational Field.” *Science* 84: 506–507. This short note gives an interesting example of Einstein’s ability to recognize important insights in the work of outsiders, even amateur scientists, such as a Czech engineer named Rudi W. Mandl. Mandl came to Einstein in April 1937 to propose the germ of the idea that we call gravitational lensing today. Mandl had already fruitlessly contacted a number of scientists with his ideas—no doubt they were repelled by some of the fantastical elements, such as the notion that lensing of this type might have caused the extinction of the dinosaurs—but Einstein spent time with him. Together they realized that a foreground star will, through the gravitational deflection of the light from another star standing directly behind it, increase the apparent brightness of the more distant star, making it easier to see. Einstein, prompted by Mandl, performed calculations to estimate the size of the effect and concluded that it would never be seen in the case of stars because of the brightness of the foreground star. Nevertheless, at Mandl’s persistent urging, he eventually agreed to publish this short note. Almost immediately, a professional astronomer, Fritz Zwicky at the California Institute of Technology, took on the idea. He pointed out that the effect probably would be observable if the two stars were replaced by two galaxies. Today, gravitational lensing is a major topic in galactic astronomy and is used routinely in many other areas of astronomy, especially in the search for exoplanets—planets that orbit stars other than the Sun. The Einstein ring (see [fig. 38](#)), often seen in lensing of galaxies, takes its name in deference to Einstein’s calculation in this paper.

1937

159. “On Gravitational Waves” (with Nathan Rosen). *Journal of the Franklin Institute* 223: 43–54. This paper had a most unusual history, as it was first submitted to the *Physical Review* under the title “Do Gravitational Waves Exist?” (See also this volume, [Part II](#), Concepts, “Gravitational Waves.”) Angered at receiving a critical referee’s report, Einstein withdrew the paper and sent it instead to the *Journal of the Franklin Institute*. Realizing that it was indeed flawed, he was eventually forced to alter it. The skepticism expressed in the original draft about the existence of gravitational waves nevertheless influenced the future careers of his assistants, Nathan Rosen and Leopold Infeld. Following his experience with this paper, Einstein never published in the *Physical Review* again, apart from a short letter.

1938

160. “Our Debt to Zionism.” Address to National Labor Committee for Palestine. *New Palestine* 28, no. 2 (April 29, 1938): 2–4. Reprinted in *Ideas and Opinions* (1954). Part of an address given in New York City, April 17, 1938. Focusing on the current troubled times for Jews, Einstein says that Zionism has renewed a sense of community among Jews, enabling many of them to escape the curse of anti-Semitism and engaging them in productive work in Palestine.
161. “Why Do They Hate the Jews?” Trans. Ruth Norden. *Collier’s Weekly* 102 (November 26, 1938): 9–10, 38. Reprinted in *Ideas and Opinions* (1954). In

answer to this question, Einstein says that Jews were the object of discrimination because they are thinly scattered throughout the Diaspora and therefore unable to defend themselves against attack, usually initiated by envious antagonists. Historically, they have been charged both with trying to assimilate and with being too clannish. He maintains that societies need heterogeneous groups, both political and social, for their invigorating effect on all aspects of life.

162. "Gravitational Equations and the Problems of Motion" (with Leopold Infeld and Banesh Hoffmann), part 1 (see no. 168 for part 2). *Annals of Mathematics* 39, ser. 2 (1938): 65–100. Using a method based on Gauss's theorem, the authors tackle the problem of motion of a system of particles in general relativity. Einstein was generally opposed to the use of singularities to describe massive bodies in such physical systems, but here he conceived the notion of concealing the singularity within a surface and performing all integrals only over the surface, thus avoiding the question of the precise details of the mass within. This important paper, known by the initials of the authors' last names as EIH, was instrumental in furthering progress in the field after Einstein's death and demonstrated conclusively an old claim of Einstein's: that the equations of motion in general relativity follow directly from the field equations, without the necessity of a separate statement of the force law.
163. "Generalization of Kaluza's Theory of Electricity" (with Peter Bergmann). *Annals of Mathematics* 39, ser. 2 (1938): 683–701. In this paper, Einstein and Bergmann explore the idea that the fifth dimension of the Kaluza-Klein theory is a real physical phenomenon. Instead of ignoring quantities that vary in the direction associated with this dimension, they assume that they exhibit a periodicity (because that dimension is "curled up on itself" or compactified on a scale too small to be seen). The mathematical difficulties this engendered were attacked by Einstein and his assistants later in no. 171.
164. *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta* (with Leopold Infeld). New York: Simon & Schuster, 1938. In this popular book, Einstein and Infeld present the ideas behind relativity and trace the development of physics since the time of Galileo. They do so without the use of mathematics, making this a useful guide for laypeople and physicists alike.

1939

165. "Our Goal." Address at a conference at Princeton Theological Seminary, May 19, 1939. Mimeograph. Reprinted as part 1 of "Science and Religion" in *Ideas and Opinions*, 41–44. See no. 170 for part 2. See also nos. 126 and 186 on the same topic. According to Einstein, scientific and rational means cannot fully serve to influence a person's convictions and beliefs—they have their limits. Therefore, the most important function of religion in our social life is to make clear a society's values and goals—the powerful traditions that have built a foundation for aspirations and values. Traditions do not need to be justified because they have already worked well in a healthy society.
166. "On a Stationary System with Spherical Symmetry Consisting of Many Gravitating Masses." *Annals of Mathematics*, ser. 2, 40 (1939): 922–936. In this paper, Einstein attempts to show that what we now call black holes cannot exist in nature. His argument is that a stellar cluster, as it contracted, would accelerate the constituent stars more and more until they were moving at almost the velocity of light. He then concludes that it would be impossible to further compress the system because one would have to add more and more energy in order to compress it more (because of relativistic effects associated with ultrarelativistic particles). Modern studies of gravitational collapse state the reverse: at this extreme concentration, it would be impossible to find the energy to prevent gravitational collapse, and such a condensed cluster of stars would collapse to form a black hole no matter how hard one tried to prevent it.

1940

167. "Freedom and Science." Trans. James Gutmann. In *Freedom: Its Meaning*, ed. Ruth N. Anshen, 381–383. New York: Harcourt, Brace. After stating that most people can agree on two goals—to satisfy their basic physical needs through the least amount of work possible, and to be spiritually content, for which they must have the chance to develop their intellectual and artistic gifts—Einstein says that the freedom to express oneself is paramount. People should limit their work time so they will have the time and strength to express themselves creatively or with independent ideas.
168. "Gravitational Equations and the Problems of Motion" (with Leopold Infeld), part 2 (see no. 162 for part 1). *Annals of Mathematics* 41, ser. 2 (1940): 455–464. In this follow-up paper, the authors generalize their earlier work so that it is coordinate-independent.
169. "Considerations concerning the Fundamentals of Theoretical Physics." Address to the 8th American Scientific Congress, Washington, DC, May 24, 1940. *Science* 91, new ser. (1940): 487–492. Reprinted in *Ideas and Opinions* (1954) as "The Fundamentals of Theoretical Physics." Einstein traces the development of theoretical scientific thinking and the attempt to find a unifying theoretical basis for each branch of science.

1941

170. "Science and Religion, Part 2." In *Science, Philosophy and Religion*, a symposium volume published by the Conference on Science, Philosophy and Religion in Their Democratic Way of Life, New York, 1941. Reprinted as part 2 of "Science and Religion" in *Ideas and Opinions* (1954), 44–49. See no. 165 for part 1. See also nos. 126 and 186 on the same topic. Einstein says that he can define science, but he cannot define religion. Therefore, if a person claims to be religious, he assumes it is someone who has values of a superpersonal, not materialistic, nature. He says that conflicts between science and religion have sprung from fatal errors, religion can learn from science to achieve its goals, and the source of the need to seek truth through science springs from the religious sphere, that is, from a faith that the rules valid for the world of existence are rational. He makes his famous remark, "Science without religion is lame, religion without science is blind."
171. "On the Five-Dimensional Representation of Gravitation and Electricity" (with V. Bargmann and P. G. Bergmann). In *Theodore von Kármán Anniversary Volume*, 212–225. Pasadena: California Institute of Technology, 1941. This paper continues the work begun in no. 163. Einstein and his collaborators attempt to overcome some of the mathematical difficulties encountered in the first paper, but merely uncover serious physical problems, such as that the gravitational field is predicted to be as strong as the electromagnetic field (whereas in reality it is far weaker for interactions between elementary particles). Einstein finally abandoned the Kaluza-Klein theory after this paper, although his idea that there is a periodicity in the hidden (or compactified) dimension did prefigure later characteristics of many versions of string theory.

1942–1943

172. "The Common Language of Science." *Advancement of Science* (London): 2, no. 5 (1942). Reprinted in *Ideas and Opinions* (1954). In this published broadcast recording to a British Association for the Advancement of Science conference in London on September 28, 1941, Einstein speaks of language as an instrument of reasoning and of the intimate connection between language and thinking.
173. "On the Non-Existence of Regular Stationary Solutions of Relativistic Field Equations" (with Wolfgang Pauli). *Annals of Mathematics* 44 (1943): 131–137. Einstein and Pauli, in their only collaboration, show that a singularity-

free stationary spacetime that is asymptotically like the Schwarzschild metric of a point mass must have vanishing mass. The same theorem is also proved for the Kaluza-Klein five-dimensional theory.

1944

174. "Remarks on Bertrand Russell's Theory of Knowledge." In *The Philosophy of Bertrand Russell*, ed. Paul A. Schilpp. Library of Living Philosophers, vol. 5. LaSalle, IL: Open Court, 1944. After expressing his admiration for Russell, Einstein discusses the evolution of philosophical thought about the objective world and the world of concepts and ideas.
175. "Gandhi's Statesmanship." In *Mahatma Gandhi: Essays and Reflections on His Life and Work*, ed. S. Radhakrishnan. London: Allen and Unwin, 1944. Einstein expresses his profound admiration for Gandhi and his leadership, famously writing that "generations to come, it may be, will scarce believe that such a one as this ever in flesh and blood walked upon this earth."
176. "To the Heroes of the Battle of the Warsaw Ghetto." *Bulletin of the Society of Polish Jews* (New York) (1944). In this two-paragraph statement, Einstein blames "the Germans as an entire people" for the mass atrocities perpetrated by the Nazi regime in Europe. They were aware of Hitler's intentions, as outlined in his book and speeches, yet they still voted for him in a landslide election.
177. "Palestine, Setting of Sacred History of the Jewish Race." *Princeton Herald*, April 14, 1944. This first of two articles written, together with Einstein's friend, the literary scholar and Zionist, Erich Kahler, is in response to the views of Philip Hitti, a distinguished professor of Semitic literature at Princeton University. Einstein and Kahler emphasize the moral right of Jews to live under self-rule in the Holy Land. Hitti's two essays and Einstein/Kahler's two responses are later republished in Kahler, *The Jews among the Nations*, pp. 123–149. New York: Frederick Ungar, 1967.

1945

178. "Einstein on the Atomic Bomb." Ed. Raymond Swing. *Atlantic Monthly* 176 (November 1945): 43–45. Articles with the same title had appeared in the *New York Times* on October 27 (p. 17) and October 29 (p. 4). Reprinted as "Atomic War or Peace, Part 1," in *Ideas and Opinions* (1954), 118–123. See no. 183 for part 2. (See also this volume, [Part III](#), Organizational Ties, "Emergency Committee of Atomic Scientists," and Political Philosophy, "World Government.") Einstein advocates a world government as a way to control the future use of the atom bomb and all armaments. It should be established, he wrote, by the three great military powers: the United States, the Soviet Union, and Great Britain. This world government would have power over all military matters and intercede in countries where oppression occurs, because a world government is preferable to the far greater evil of wars. The Russian Academy of Sciences later denounced Einstein for advocating such a system (see *Ideas and Opinions* [1954], 134–140).
179. "A Testimonial from Prof. Einstein." In Jacques Hadamard, *An Essay on the Psychology of Invention in the Mathematical Mind*, 142–143. Princeton, NJ: Princeton University Press, 1945. Princeton Science Library edition: appendix, in *The Mathematician's Mind: The Psychology of Invention in the Mathematical Field*. Princeton, NJ: Princeton University Press, 1996. Einstein replies to a questionnaire sent to mathematicians by Hadamard, a French mathematician, for a survey on how their mental processes work.

1946

180. "Social Obligation of the Scientist." In *Treasury for the Free World*, ed. R. Raeburn. New York: Arco, 1946. This book originated from the files of *Free World*, a publication that disseminated the ideas of international leaders and public officials on the urgent problems of the time. While it was being

prepared, the atom bombs fell on Japan. In the book, sixty-one world-famous figures, including Charles de Gaulle, Fiorello La Guardia, Marshal Tito, Julian Huxley, and Einstein, give their opinions on the current world situation. Einstein's essay is presented in the form of a questionnaire. He is asked (1) how can scientists make their influence felt toward the aim of world cooperation (through the establishment of an international body that presides over military matters); (2) should scientists concern themselves with political matters (every citizen should express his convictions); (3) is there a relationship between the progress of physics and mathematics and the progress of society (yes, because they bring about new technology and because they are efficient counterweights to a materialistic attitude); and (4) what can be done to undo the effects of Nazism ("the Germans can be killed or constrained, but they cannot be re-educated to a democratic way of thinking and acting within a foreseeable period of time").

181. " $E = mc^2$: The Most Urgent Problem of Our Time." *Science Illustrated* 1 (April 1946): 16–17. Reprinted in *Ideas and Opinions* (1954). Einstein gives an explanation of the world's most famous equation—the formula for the equivalence of mass and energy—in his own words for the general reader.

1947

182. "The Military Mentality." *American Scholar* 16 (1947): 353–354. Reprinted in *Ideas and Opinions* (1954), 132–134. Einstein accuses America of placing the importance of aggressive power above all other factors that affect relations among nations, resulting in a military mentality in government. He warns that Germany's similar attitude, beginning with Bismarck and Kaiser Wilhelm II, resulted in Germany's decline in less than a century. A military mentality is even more dangerous today because weapons are more powerful.
183. "Atomic War or Peace." As told to Raymond Swing. *Atlantic Monthly* 180 (November 1947): 29–33. Reprinted as "Atomic War or Peace, Part 2," in *Ideas and Opinions* (1954). See no. 178 for part 1. Einstein speaks in favor of outlawing the atom bomb and again advocates a world government for the purpose of averting wars. The Emergency Committee of Atomic Scientists distributed a reprint of this article with a plea for financial support.
184. [Response to the editor on Walter White's article, "Why I Remain a Negro."] *Saturday Review of Literature* 30 (November 1, 1947): 21. Walter White, the secretary of the NAACP, had written an article about his life for the *Review* in October. In it, he described how he, a blue-eyed and fair-skinned Negro, could have passed for white but chose instead to advocate for civil rights as a black man. Einstein stated: "There is only one road to true human greatness—through suffering."

1948

185. "A Reply to the Soviet Scientists." *Bulletin of the Atomic Scientists* 4, no. 2 (February 1948): 35–37. Writing in December 1947, Einstein responds to the charge made by four prominent Soviet physicists that his call for world government is merely a cover for American hegemonic ambitions. He protests that his only objective in advancing world government is to eliminate a nuclear arms race that would destroy humanity, socialist and capitalist alike. (See also this volume, [Part III](#), Political Philosophy, "World Government.")
186. "Religion and Science: Irreconcilable?" *Christian Register* 127 (June 1948): 19–20. Reprinted in *Ideas and Opinions* (1954). (See also this volume, [Part III](#), Religion.) In this response to a greeting sent by the Liberal Ministers Club of New York City, Einstein states that the answer to the question is complicated because, though people can agree on what science is, they often differ on a definition of religion. The mythical aspect of religion—which is only one aspect of it—is the part that is most likely to cause conflict, and myths are not necessary to pursue religious goals.

187. "On Receiving the One World Award." An address given at Carnegie Hall, April 27, 1948. Reprinted in *Ideas and Opinions* (1954). Distraught by the consequences of the recent war and the prospect of continuous rearmament, Einstein again proposes that there is only one path to peace and security: a supranational organization.
188. "Quantum Mechanics and Reality" (Quantenmechanik und Wirklichkeit). *Dialectica* 2 (1948): 320–324. Einstein restates his belief that the wave function of an individual particle represents only incomplete information about its true physical position and momentum. He believes that ultimately a more complete theory will be found that will incorporate quantum mechanics in the same way, perhaps, that geometrical optics is incorporated into the more complete theory of wave optics.
189. "Atomic Science Reading List." In '48: *Magazine of the Year* (January), 60–61. Maintaining that "it is not enough to know all about isotopes and pitchblende and plutonium" in order to understand atomic energy and its capabilities, Einstein selects and describes six periodicals and books that cover scientific and historical sources as well as the "problems of peace, security, and the continued life of man with man." These are the *Bulletin of the Atomic Scientists*, a monthly publication, which he says is the most valuable single source of up-to-date information on atomic energy; Selig Hecht's *Explaining the Atom* (1947), an account of the scientific steps that have led to our present knowledge on nuclear fission; John Hersey's *Hiroshima* (1946), a novel describing the impact of the atomic bomb on everyday people; Cord Meyer, Jr.'s *Peace or Anarchy* (1947), a review of the complex problems connected with peace and security; Emery Reves's *The Anatomy of Peace* (1945), which discusses the issues of peace and the need for a world government to secure it; and Raymond Swing's *In the Name of Sanity*, which contains discussions of the events that followed the news that atomic energy had been discovered.

1949

190. "Why Socialism?" *Monthly Review: An Independent Socialist Magazine* 1 (May 1949): 9–15. Reprinted in *Ideas and Opinions* (1954). (See also this volume, [Part III](#), Political Philosophy, "Socialism.") Though advocating a socialist economy in the interests of social justice, Einstein warned in this essay of the need to protect the rights of the individual in the face of a centralizing, permanent bureaucracy.
191. "Autobiographical Notes" and "Remarks to the Essays Appearing in this Volume." In *Albert Einstein: Philosopher-Scientist*, ed. Paul A. Schilpp, pp. 3–94 (in German and English), and pp. 665–688. Library of Living Philosophers, vol. 7. La Salle, IL: Open Court, 1949. Einstein facetiously referred to these Notes, which he wrote in 1946 as a short scientific autobiography, as his "obituary."
192. "On the Motion of Particles in General Relativity Theory" (with Leopold Infeld). *Canadian Journal of Mathematics* 3 (1949): 209–214. The authors show that the field equations alone suffice as a basis for solving the problem of motion in general relativity theory, since the Einstein equations not only determine how particles must respond to gravitational forces, but also contain the information necessary to describe those forces. (In contrast, in Newtonian theory the laws of motion and the law of gravitation are given completely separately from each other.)

1950

193. "On the Generalized Theory of Gravitation." *Scientific American* 182, no. 4 (April 1950): 13–17. Reprinted in *Ideas and Opinions* (1954). At the request of the editors of the magazine, Einstein discusses his mathematical investigations into the foundations of field theory in physics.
194. "Introduction." In Philipp Frank, *Relativity: A Richer Truth*. London: Jonathan Cape, 1951. In the foreword to this small book on the ethical implications of relativity, Einstein writes that it may seem that logical

thinking is not relevant for ethics, but that, indeed, “ethical directives can be made rational and coherent by logical thinking and empirical knowledge.” He states that ethical axioms, like the axioms of science, are established and then tested; if they fit society or an individual, they are accepted.

1951–1952

195. “Introduction.” In Carola Baumgardt, *Johannes Kepler: Life and Letters*. New York: Philosophical Library, 1951. For this collection of annotated letters from Kepler to his contemporaries, including Galileo, Einstein wrote an introduction tracing how Kepler determined the movement of the Earth in planetary space. Because Earth “itself can be used at any time as a triangulation point, Kepler was also able to determine by observation the true movements of the other planets.” The letters show, he says, that Kepler completed his work under conditions of great personal hardship.
196. “Foreword.” In Dagobert D. Runes, ed., *Spinoza: Dictionary*. New York: Philosophical Library, 1951. Einstein praises this dictionary of Spinoza’s terminology rendered in Spinoza’s own words as a reliable guide to the philosopher’s works, which are otherwise often difficult to understand.
197. “Foreword.” In Homer Smith, *Man and His Gods*. Boston: Little, Brown, 1952. In this history of religious and philosophical thought by a prominent biologist, Einstein praises this scientist’s objectivity in presenting his subject. He says such objectivity is rarely found in a “pure historian.”
198. “Those Who Read Only Newspapers See Things Like a Nearsighted Person with No Glasses” (Wer nur Zeitungen liest, sieht die Dinge wie ein Kurzsichtiger ohne Augengläser). *Der Jungkaufmann* (Zurich) 27, no. 4 (1952): 73. See *Ideas and Opinions* (1954), 64–65, for an English translation. Einstein states his belief that it is important for young people to read the classics. Because there are only a few exceptional people of letters in any given century, their work is “the most precious possession of mankind.”
199. “On the Moral Obligation of the Scientist.” Trans. Ira Freeman. *Bulletin of the Atomic Scientists*, February 1952, pp. 34–35. First presented in 1950 as a message to the Italian Society for the Advancement of Science. Einstein examines the question of whether scientists can undertake research as an independent intellectual exercise or if science should lead to practical applications. He fears that, paradoxically, scientists have suffered a tragic fate because they are losing the very freedom and independence they once enjoyed while advancing science and are subordinating themselves to practical objectives. He regards this situation as a moral dilemma that needs to be examined carefully.
200. “Symptoms of Cultural Decay.” *Bulletin of Atomic Scientists* 8, no. 7 (October 1952). Reprinted in *Ideas and Opinions* (1954). Einstein writes that politicians should not control the sciences and impede free scientific exchange with other countries. The attitude now is one of such distrust that even in peacetime our lives and work have to be organized as if we are preparing to win a war.

1953

201. “A Comment on a Criticism of Unified Field Theory.” *Physical Review* 89 (1953): 321. This was Einstein’s final paper on the unified field theory. He was certain about the mathematical concepts but uncertain about the physical aspects.
202. “Letter in Reply to William Frauenglass.” *Bulletin of the Atomic Scientists* 9 (1953): 230. Reprinted in *Ideas and Opinions* (1954). In this letter of May 16, 1953, written during the McCarthy witch-hunting era, Einstein advises Brooklyn teacher William Frauenglass to refuse to submit to questioning by the U.S. Senate’s Internal Security Subcommittee. All intellectuals should refuse to testify, not on the basis of the Fifth Amendment but because it is shameful for an innocent citizen to be forced to submit to such an inquisition, which Einstein considers a violation of the spirit of the

Constitution.

1954

- 203. *Ideas and Opinions*. Trans. Sonja Bargmann. New York: Crown, 1954. The most popular anthology of Einstein's writings in English, still in print, though some of the presentations are not faithful to the published originals.
- 204. "Algebraic Properties of the Field in the Relativistic Theory of the Asymmetric Field" (with Bruria Kaufman). *Annals of Mathematics* 59 (1954): 230–244. *See also* no. 206. This was Einstein's first paper with a female collaborator, his assistant at the time. In the paper, they seek to modify the field equations of general relativity in order to permit asymmetries in the field. In particular, the affine connection is asymmetric, often described as a torsion tensor. Einstein hoped that this approach would lead to a natural expression of the intrinsic spin of fundamental particles. Thus, as with so much of his work on relativity in his later years, this theory is ultimately part of his broader unified field theory program.
- 205. *The Meaning of Relativity*. 5th ed. Princeton, NJ: Princeton University Press, 1954. This book is the final edition of Einstein's seminal work. In it, he completely revises appendix 2, "Generalization of Gravitation Theory," of the fourth edition, renaming it "Relativistic Theory of the Non-Symmetric Field"—his final attempt to extend or generalize his theory to achieve a unified theory of at least the gravitational and electromagnetic fields.

1955

- 206. "A New Form of the General Relativistic Field Equations" (with Bruria Kaufman). *Annals of Mathematics* 62 (1955): 128–138. *See also* no. 204. This was Einstein's final scientific publication and gave the final form of the field equations for general relativity, based on the asymmetric affine connection approach on which he had been working for the last several years of his life. In spite of Einstein's hopes for it, the theory did not have any influence within the field of general relativity, nor with the rest of physics. A final report on the progress of his work was presented within months of his death by his collaborator Bruria Kaufman at the 1955 Bern conference to commemorate the fiftieth anniversary of relativity theory. This conference brought together many people who were interested in general relativity and was influential in sparking a resurgence of interest in the subject, which led to its ultimately becoming a major field of physics. Today it is sometimes referred to as GR0, the prequel to a series of conferences devoted to GR (general relativity).
- 207. "The Russell-Einstein Manifesto." Issued from London, July 9, 1955, and published worldwide. *See this volume, Part III, Political Contexts, "Postwar and Cold War,"* for the complete statement, or *see* www.nuclearfiles.org.
- 208. "Remembrances" (Erinnerungen-Souvenirs). *Schweizerische Hochschulzeitung* 28 (special volume), pp. 145–153. In this remembrance of his Swiss school days, Einstein recalls, among other things, that he studied the work and lives of the "masters of theoretical physics" while he was a student.
- 209. "Albert Schweitzer at Eighty." Privately printed by Homer A. Jack, in *To Albert Schweitzer: A Festschrift Commemorating His Eightieth Birthday*; reprinted in *Christian Century* 72, no. 2 (1955). Einstein shows appreciation for the aging theologian, organist, philosopher, and physician, best known for his medical mission in Lambaréné, present-day Gabon in West Africa. He admires his robust health and his "ideally fused" kindness and yearning for beauty.

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- pitt.edu/~jdnorton/jdnorton.html (Website of John Norton, a historian and philosopher of science). The site provides many of his articles for download, in addition to other material for those interested in Einstein, written at an accessible level.

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